SECONDARY SCHOOL SCIENCE

J. H. PHEASANT
M.A., B.SC., F.L.S.
Institute of Education, University of London

AND

S. J. PARKIN
M.A., B.SC., A.INST.P.
Lecturer in the Department of Applied Physics at the Northampton Polytechnic
formerly Lecturer in charge of Science, Cordwainers Technical College

The Third of a Series of Four Books

BOOK ONE
How we Learn about the World around us

BOOK TWO
The Science of Our Surroundings

BOOK FOUR
The Science of Life and Leisure

SECONDARY SCHOOL SCIENCE

BOOK THREE

Ourselves and Science

J. H. PHEASANT

S. J. PARKIN

ILLUSTRATED BY IAN T. MORISON, D.A.

LONDON: GEORGE ALLEN AND UNWIN LTD

First published in 1956
Second Impression 1958

Printed in Great Britain
in 12 point Imprint type
by Unwin Brothers Limited
Woking and London

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BOOK 1 gives a preliminary view of the nature of matter, and of the senses through which we apprehend it; of some of the instruments which extend the range of our senses and of the scientific principles underlying them. There is a chapter on practical work in the Science Room. It ends with an important biological project on the Oak Tree and the life associated with it, animals, birds, insects, fungi. There are also practical appendices on bird study, on how to keep and study insects, etc.

BOOK 2, *The Science of Our Surroundings*, deals at a more advanced level with the nature of the world in which we live and particularly with the science of the home, i.e. environment in relation to Man. There is work on the universe, the earth, minerals, living things past and present, weather, the structure of the house, energy in the home, and water. The project is on a Pond.

There is an appendix on making the necessary apparatus and setting up a meteorological station at school.

BOOK 4, *The Science of Life and Leisure*, is arranged as a series of topics, each complete in itself. 1. Bacteria and public health. 2. Heredity. 3. Field work. 4. Making use of natural sources of energy. 5. Photography. 6. The Science of fabrics.

CHAPTER 1

What Matter is Made Of

ELEMENTS

ALL SUBSTANCES on the earth, whether they are solid, liquid or gas are built up from about one hundred different kinds of particles. These particles, which cannot be seen even through the most powerful microscope, are called *atoms*. A substance built up from only one kind of atom is called an *element*. It used to be thought that there were only ninety-two elements but scientists have discovered new ones and may yet find others.

WELL-KNOWN SUBSTANCES WHICH ARE ELEMENTS

SOLIDS Iron, copper, zinc, lead, aluminium, magnesium, nickel, chromium, tin, silver, gold and sodium, which are all metals. Sulphur and iodine.

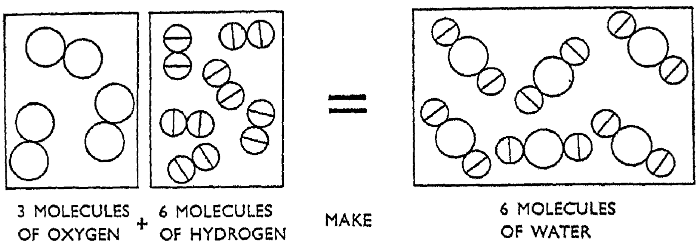
LIQUIDS Mercury (a liquid metal).

GASES Oxygen, nitrogen, hydrogen, neon and chlorine.

As a rule atoms do not exist alone. They link together to form larger particles called molecules. The atoms of both oxygen and hydrogen link together in pairs to form molecules of those gases. When molecules consist of only one type of atom they are molecules of elements.

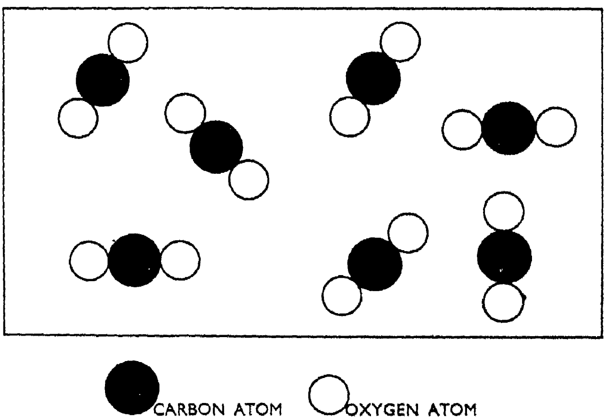
COMPOUNDS

If atoms of different types link together they form molecules of compounds. When one atom of the gas oxygen links with two atoms of the gas hydrogen a molecule of water is formed. The liquid, water, is a compound of the gases oxygen and hydrogen.

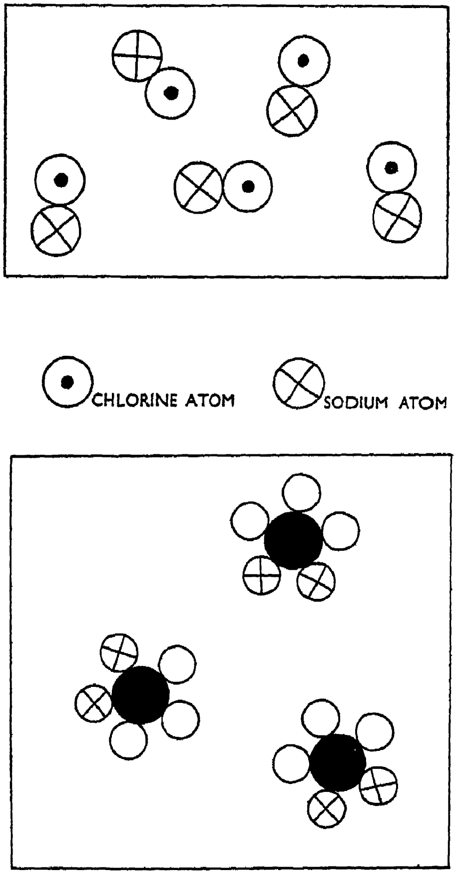


Some Other Compounds

Carbon dioxide—one atom of carbon (a black solid) linked to two atoms of oxygen (a gas in which things burn). Carbon dioxide is a gas which puts out a flame.



Carbon Dioxide



Sodium chloride (common salt)—one atom of sodium (a dangerous solid) linked to one atom of chlorine (a poisonous gas). Sodium chloride is a white solid essential to our bodies.

Sodium carbonate (washing soda)—two atoms of sodium linked to one atom of carbon and three atoms of oxygen.

Compounds have properties quite different from the properties of the elements which form them.

SOLIDS, LIQUIDS AND GASES

Solids are substances in which the molecules are tightly packed together in an orderly fashion. The molecules are rather like rows of tightly packed spectators in a football crowd and no molecule can move far. Solids have a definite size and shape.

In *liquids* the molecules are far enough apart to move about. The molecules are like the people in a crowd in a market place; they all stay in the market place but they can move from stall to stall. Liquids always occupy the

same amount of space but take the shape of the container they are in.

In *gases* the molecules are widely spaced and move about freely in all directions. Releasing a cloud of gas molecules into the air would be very much like letting the crowd from an international football match go home. They would travel in all directions and there would be no limit to the distance they might travel. As they get further from the stadium, so they are more widely spread. A gas has no shape and its molecules will spread out to fill a space of any size in which it is placed.

Solids, liquids and gases may be either elements, compounds or mixtures.

MIXTURES

When different elements or compounds are mixed together and a new compound is not formed, the result is called a mixture. The chemicals in a mixture can be separated out, sometimes very simply.

If you stir or grind sulphur powder and iron filings together you get a dirty grey mixture. It looks at first as though you have a new substance, but if you look at the mixture through a magnifying glass you will see the dark specks of iron and the specks of yellow sulphur quite separate from one another. If you stir the mixture with a magnet, iron filings will be removed by the magnet, leaving the sulphur behind.

It is possible to make a *compound* of iron and sulphur by heating a mixture of the two in a test tube. The compound, which is called iron sulphide, is quite different from the two elements which form it.

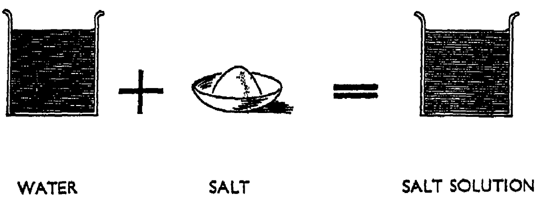
Air is a mixture of the gases oxygen, nitrogen, water vapour and carbon dioxide. When animals and plants

breathe, they use up the oxygen and give out carbon dioxide. When things burn they use up the oxygen and, if they contain carbon, they also give off carbon dioxide. On the other hand plants are able during daylight to use carbon dioxide from the air and to give off oxygen in its place.

The alloys of metals are also mixtures. Brass is an alloy made by melting copper and zinc together and then letting the mixture solidify.

Solutions

These are a special kind of mixture. When salt is stirred into water it completely disappears, forming a solution. The salt has broken up into molecules which have spread evenly through the water and can no longer be seen.



If a dye powder had been used instead of salt, the result would have been an evenly coloured solution. In these two cases the water is called the solvent and the salt or dye is called the solute.

SOLVENT + SOLUTE = A SOLUTION

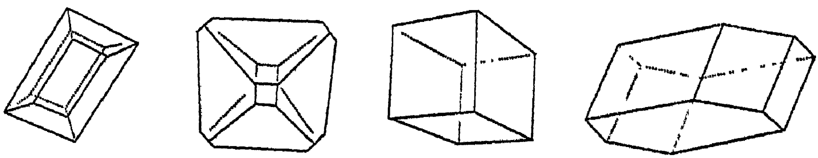
Any liquid may be a solvent, and either solids, liquids or gases may be solutes. Solutions are always clear although they may be coloured.

EXAMPLES OF SOLUTIONS

Solvent		*Solute*		*Solution*
Water	+	salt (a solid)	=	salt solution
Water	+	methylated spirit (a liquid)	=	methylated spirit solution
Water	+	carbon dioxide (a gas)	=	soda water (or carbonic acid)
Methylated spirit	+	shellac (a solid)	=	shellac varnish

We can get a solid back from a solution by allowing the liquid to evaporate away. The solid left behind often has a very angular shape and is called a *crystal*. Common salt is composed of crystals which are tiny cubes.

CRYSTALS



Copper Sulphate Alum Salt Washing Soda

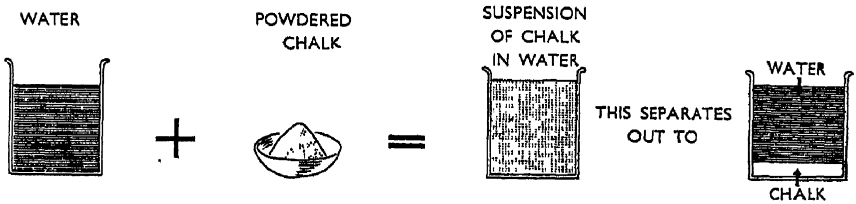
Suspensions

When powdered chalk is stirred into water it does not dissolve but spreads evenly through the water. If it is left for a few minutes the chalk settles to the bottom of the container. A mixture like this, which contains a liquid and a powder which will not dissolve in it, is called a suspension.

Household paints and distempers, and white shoe cleaner, are examples of suspensions of powders in a liquid. Many medicines and household cleaners for

windows and metals are also suspensions. If they are allowed to stand, the powder settles to the bottom of the container. The label "Shake before using" or "Stir before using" warns you that the contents of a tin or bottle will separate out if they are left undisturbed. Suspensions are always cloudy.

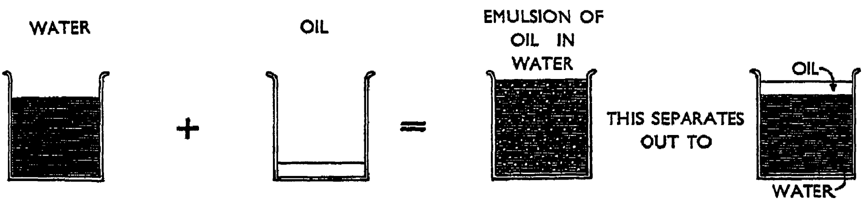
Suspensions of powder in a liquid can be separated by



filtering. By pouring them through a special filter paper, which is like blotting paper, the powder is trapped and the liquid passes through.

Emulsions

When a small amount of oil is shaken up with water it breaks up into a large number of tiny balls of oil which



spread evenly through the water. When the shaking is stopped the oil gradually separates out and forms a layer on top of the water, the largest drops separating first, and the very small ones taking a long time to rise to the surface. A mixture in which one liquid is broken up into tiny

droplets which spread through another liquid is called an emulsion. It is a special sort of suspension. Milk is an emulsion, and many medicines (cod-liver oil emulsion), hair creams, cosmetics and liquid polishes are also emulsions. Most emulsions are milky in appearance.

PHYSICAL AND CHEMICAL CHANGES

When ice melts, it changes into water. It looks as though a new substance has been made, but, in fact, the chemical is still the same although it is in a different form. When water is heated and turns into a vapour it is still the same chemical. Changes like this, which occur without a new chemical being formed, are called physical changes. Only the form of the substance taking part is changed.

When magnesium is burned in air it turns into a white powder. This is a new chemical, magnesium oxide, which is formed by the joining of the magnesium with oxygen from the air. A change like this, in which a new chemical is formed, is called a chemical change.

MORE ABOUT ATOMS AND MOLECULES

Atoms and molecules are never completely at rest even in the stiffest and hardest of solids. They are constantly vibrating. The hotter an object becomes, the more violently do its atoms and molecules vibrate. If the vibration becomes great enough they may break away from one another, and when this occurs a solid may turn into a liquid or a liquid may turn into a vapour. If a gas is cooled down far enough the vibrations of its molecules become smaller and they will move closer together and form a liquid. In the same way liquids which are cooled enough may become solids, as when water turns into

ice. It is the vibrations of molecules which we sense as heat.

All atoms have a heavy centre, called the nucleus, surrounded by tiny particles, called electrons. It is the electrons which link atoms together to make molecules of elements and compounds.

Some atoms, for example, the atoms in copper, contain electrons which can easily be made to break away. If a number of these electrons are made to flow in one direction we get a flow of electricity.

TEN QUESTIONS TO ANSWER

1. What do we call the particles which join together to make all chemical substances?

2. What do we call a substance formed when different elements join together?

3. What are the main differences between solids, liquids and gases?

4. What would you do to sea-water to get the salt from it?

5. Describe how you would separate the solid from the liquid in a suspension.

6. What do we call the mixture made by shaking together two liquids which do not make a solution?

7. What are the chemical names for common salt and washing soda?

8. Write down two examples of a physical change and two examples of a chemical change.

9. What happens to the atoms and molecules of a substance when we heat it?

10. What is the name of the particles whose movement makes an electric current?

THINGS FOR YOU TO DO

1. Make a list of all the elements you have met. Write a few words beside each name describing its form (solid, liquid or gas), its colour, its smell, or any other point which you think is important.

2. Make small balls of white plasticene to represent atoms of oxygen, red ones to represent hydrogen atoms, blue ones for carbon atoms, yellow for sodium atoms and green for chlorine atoms. Stick them together to make models of the molecules of the elements and compounds written about in the chapter. Later you can make others.

3. Do the experiments with iron and sulphur described on page 12. Say why you think you have made a new substance by heating the mixture.

4. Will any of the following substances dissolve in methylated spirit? Machine oil, salt, shellac, glycerine, rosin, gum arabic, iodine, paraffin wax, linseed oil.

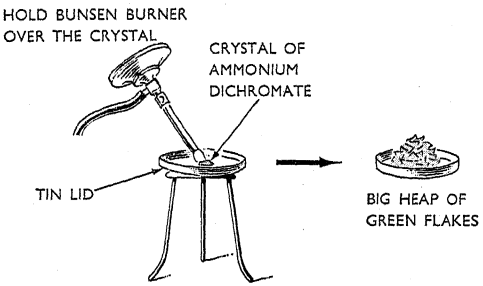
Carry out experiments and make a list of the results.

5. See which of the materials, if any, in the list in question 4 will dissolve in turpentine.

6. Heat a few iodine crystals in a test tube and hold a cold tile near the mouth of the tube. The grey iodine crystals turn into a violet vapour. What happens when the violet vapour touches the cold tile? Has any new chemical been formed? Are the changes which take place physical or chemical changes?

7. Heat a small amount of each of the following substances in a test tube: Sugar, candle wax, bread, wood, coal dust, a crystal of copper sulphate, a 1 inch length of magnesium ribbon, a small piece of copper, copper carbonate and mercury oxide. Watch carefully and write down all that you see. Let the tube cool down and watch what happens to the substance in it.

Make a list of your observations and write against each substance whether the change which takes place is a physical or chemical change.



8. Obtain some orange ammonium dichromate and heat a *small* crystal of it on a tin lid. Watch carefully. When the crystal smoulders take away the burner. You start with an orange crystal which forms a small volcano and leaves you with a big heap of green flakes.

What happens to the green flakes when they cool? Is the change which takes place a physical or chemical change?

9. Heat cooking fat in a pan. Describe what happens. Allow it to cool. Are these chemical or physical changes?

10. One third fill an evaporating basin with dilute hydrochloric acid. Hold one end of a piece of mauve litmus paper in it. What colour does the paper turn? Now add, drop by drop, some dilute caustic soda solution. Stir the liquid after each drop. When the paper turns mauve again you will have neutralised all the acid and made a new chemical substance. A chemical change has taken place. Pour the liquid into an evaporating basin and evaporate until all the liquid has gone. The white substance left in the basin is common salt.

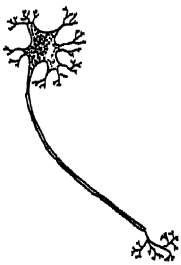
CHAPTER 2

The Human Body

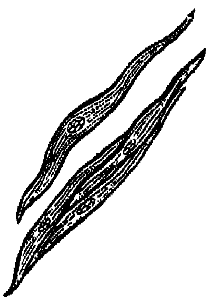
IN BOOK I we learned that the nervous system of the body keeps us in touch with our surroundings. We also learned something about those parts of the body that receive messages from the world around us—the eye, ear, nose, tongue and skin. Now we shall learn more about how the body works.

CELLS

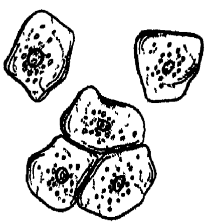
The body is made up of an enormous number of very small cells. These have different shapes according to the work they do. When a large number of the same kind of cell occur together and do one special job we say that they form a tissue. For instance, the many muscle cells at the top of your arm which all contract together when you lift a weight form muscle tissue. Here are drawings of some



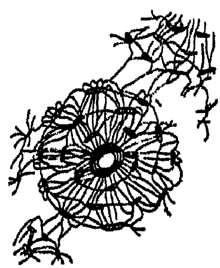
A nerve cell



Muscle cells



Cells from the inside of the human cheek



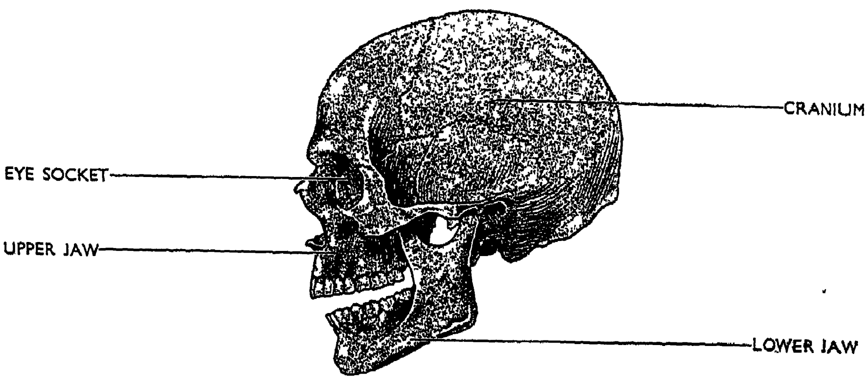
Bone cells

of the cells of the body. They are all magnified many times.

Different tissues are grouped together to form organs. The heart, liver and lungs are organs.

THE SKELETON

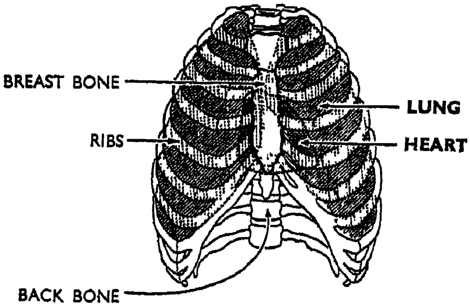
The soft tissues of the body need a firm, rigid support. The bony skeleton gives this support and enables us to stand and sit upright. The skeleton also helps us move. The muscles of the arms and legs are joined to the limb bones and so, when these muscles contract, the limbs move (see Book I). The bones of the arms and legs are levers or machines which help us to do work. The jaw bones also act as a lever. Can you find the position of the muscles which work the jaws? Can you move both jaws or only one?



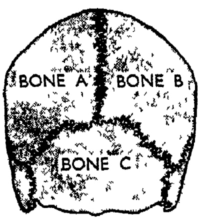
The human skull

The skeleton protects the soft organs of the body. The brain is protected by a bony case, the cranium or brain box. The heart and lungs are surrounded by a bony case made of the ribs, the breastbone and the backbone.

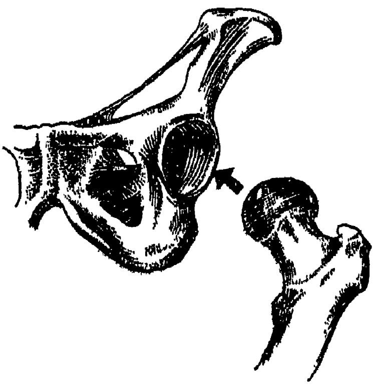
The skeleton is made up of a large number of separate bones. Where two bones meet, there is a joint. Some of the joints allow the bones to move one against the other, and so we can move parts of the body easily and quickly. The bones making the cranium, however, do not move. They fit together with zigzag joints. Look for these immovable joints on a dog's or a rabbit's skull. Here are drawings of some of the joints in the body.

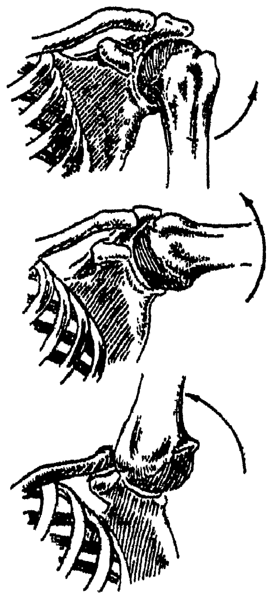


The bony case protecting heart and lungs



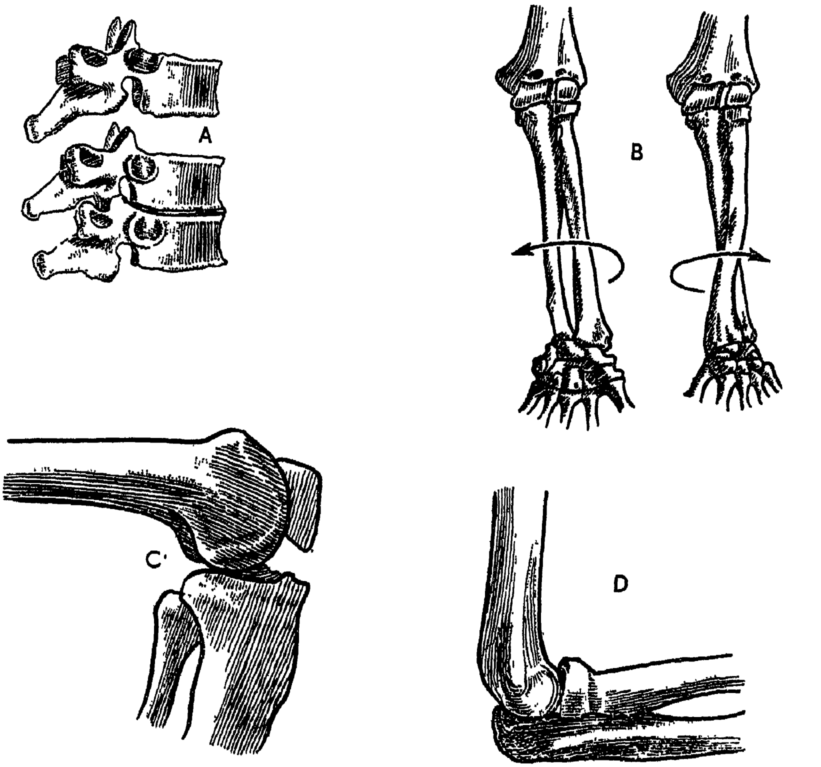
Zigzag immovable joint in the cranium


Ball and socket joint at the hip (not easily put out)


Ball and socket joint at the shoulder (easily put out)

The backbone is made of a row of bones called vertebrae. Each vertebra is shaped rather like a cotton reel.

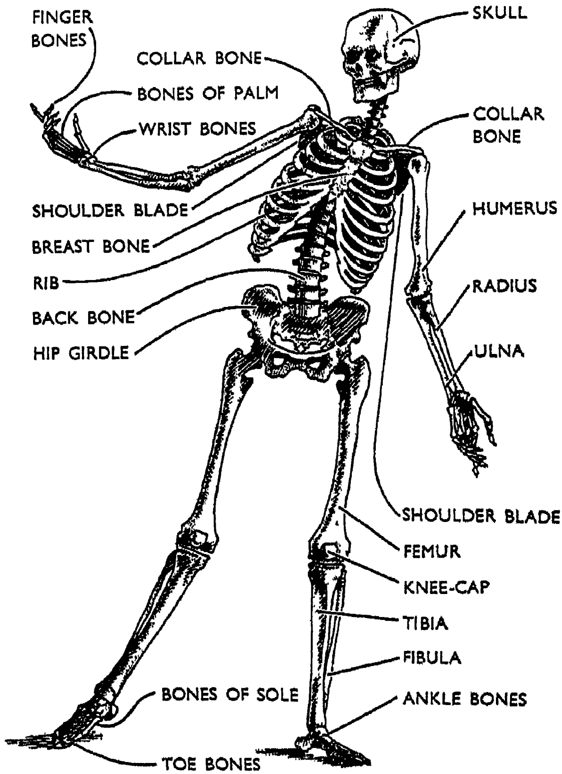
The backbone protects the delicate nervous tissue of the spinal cord, which passes inside the vertebrae. Did you know that almost all mammals, whatever their size, have seven vertebrae in the neck? The giraffe has only seven



A. Gliding joints between bones of the backbone
B. Peg joint which turns the hand
C. Hinge joint of the knee
D. Hinge joint of the elbow

in its long neck, human beings have seven and so has the mouse! The vertebra nearest the head is the atlas. On it the head nods, up and down. Just beneath it is the axis. This bone has a peg which fits into the atlas and

enables us to turn the head. On the drawing of the skeleton we have labelled some of the larger bones of the body in case you want to learn their names.



The human skeleton

The skeleton therefore

(1) Supports the body;
(2) Protects the soft organs;
(3) Enables the body to move about easily;
(4) Helps us to do work.

THE NERVOUS SYSTEM

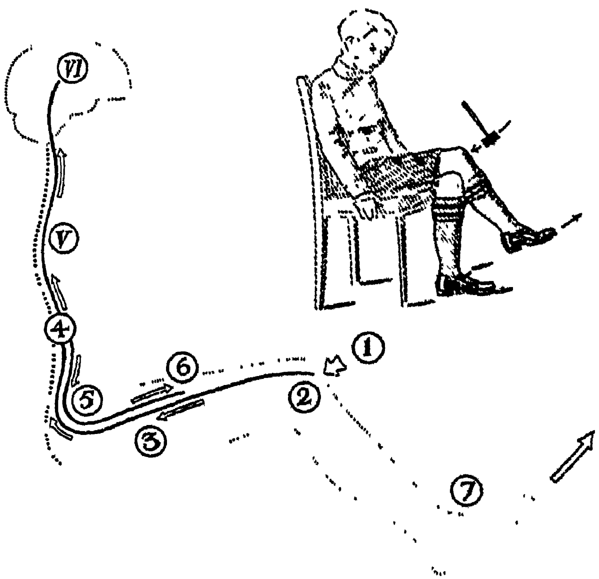
As well as keeping us in touch with our surroundings, the nervous system also keeps all the parts of the body working together as a team. When we see a juicy pear we say that it makes our mouths water. You can already work out the first things that happen, because you know from Book I that when your eyes see the pear, they send a message along a nerve to the brain. Then the brain sends out a message along another nerve, this time to glands which make the watery juice, saliva. The saliva helps you to digest the pear if you get a chance to eat it. You do not have to think about producing the extra saliva; your body makes it when you see the tasty food. We call this kind of action a reflex action. There are many of these reflex actions taking place in our bodies and we are usually quite unaware that they are happening.

When anything comes very near your eyes, you shut them quickly, even before you have time to think what is happening. This is the result of another reflex action. When you touch a hot object you immediately move your hand away and so you do not get badly burned. By these two reflex actions your nervous system is protecting you from damage. When our nervous system is fatigued, our reflex actions are slower than they should be. Enough rest, exercise, fresh air and good food help to keep the nervous system working at its best.

Here is a reflex action which the doctor tests if he wishes to check that your nervous system is working properly. Sit on a chair with one leg crossed over the other. Shut your eyes while a friend taps your leg smartly just below the knee cap. Can you work out why your leg jerks up? Check your idea from the drawing on page 26.

One rather unpleasant reflex action takes place when food in the stomach cannot be digested. After a time the

nerve ends in the stomach pick up a message that the food has been there too long. The message travels to a nerve centre in the spinal cord and this sends out another



A reflex action

The stimulus (the tap) (1) is received by nerve endings in the skin (2). The sensory nerve (3) conducts the stimulus to the nerve centre in the spinal cord (4) where it is transferred to a motor nerve (5) attached to the leg muscles (6) which contract and the foot jerks up.

In addition to this reflex action, the stimulus (in this example) travels from (4) along another sensory nerve (V) to the brain (VI), and the boy feels the tap.

message to the muscles of the stomach wall. They contract and push the food upwards out of the stomach. This reflex action makes us sick.

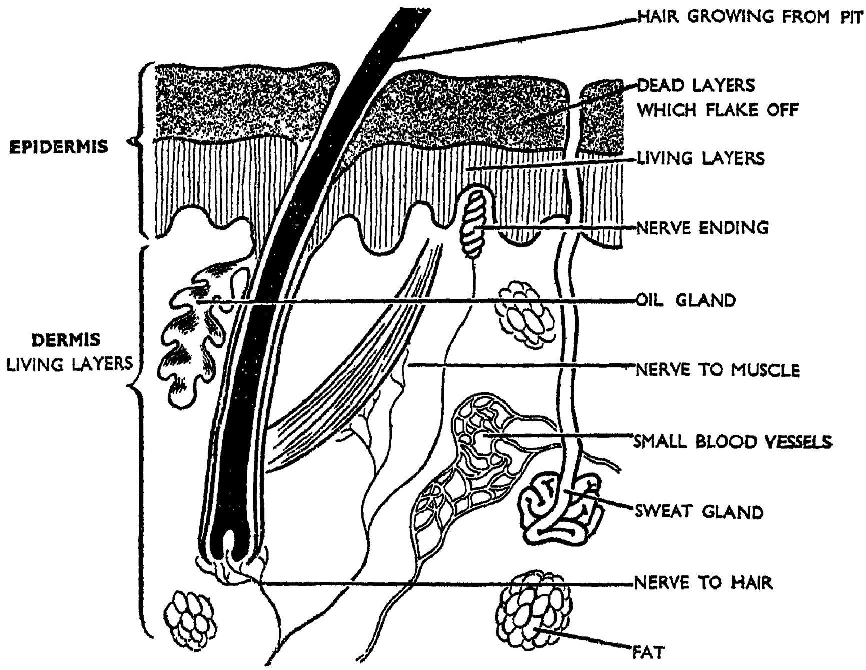
THE BRAIN

The brain is the headquarters of the nervous system. Human beings have a much more elaborate brain than any

other animal. We can think and reason things out for ourselves. The lower animals cannot do this.

THE SKIN—THE BODY'S FIRST LINE OF DEFENCE

There are large numbers of disease bacteria (germs) in the air around us. The skin is one of the body's defences



against these bacteria. Skin covers the whole of the outside of the body. The skin inside the mouth and in the lungs is very thin and delicate, but over most parts of the body it is thicker. Disease bacteria cannot penetrate the skin if there are no cuts, scratches or sore places on it. If you cut yourself, it is wise to put an antiseptic on the cut. An

antiseptic checks reproduction of bacteria. If you look at a section of the skin under a microscope you will see something like the diagram shown on the previous page.

Look at the surface of the skin with a magnifying glass. Sketch a small piece of it to compare what you see with the microscope section. Besides protecting the body from attacks of disease bacteria, the skin has other useful functions:

1. It helps us to feel (see Book I).

2. It helps to control the temperature of the body (Chapter 7).

3. It helps to get rid of waste substances as perspiration (Chapter 5).

4. It can absorb certain ointments and liquids. A doctor can sometimes give a patient something to rub into the skin instead of giving medicine to drink.

5. In bright sunlight, the skin makes extra supplies of a brown pigment which protects the delicate layers underneath from injury. Too much very bright sunlight is harmful to the body.

Nails and hair grow from the skin. They are made by the living protoplasm of the deeper layers of the skin, and they are protective. Nails are made of a horny substance. They should be kept short and clean. Hair should be washed regularly. A well-cared-for skin and well-kept nails and hair help us to look attractive to other people and also help to keep us in good health.

We said in Book I that the skin should be washed with a pure soap to remove dirt, grease and perspiration. If these are not removed often enough, a bad complexion may result. Spots and boils may also be due to eating

the wrong food or drinking too little water (see Chapter 5) or to insufficient exercise or sleep.

THE BLOOD—THE BODY'S TRANSPORT SYSTEM

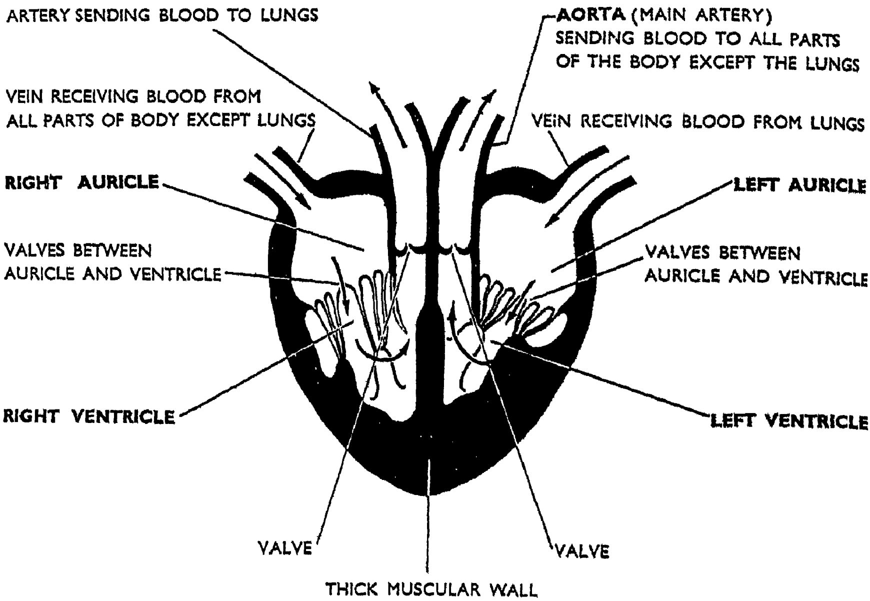
A good transport system is needed to carry substances about the body. The blood is the body's transport system. There are nine to ten pints of blood in an adult and it is always moving round the body carrying substances in it. The time taken for blood to travel from your left arm all round the body and back to the left arm again is less than half a minute! The blood supplies all parts of the body with the food and oxygen they need. It also removes waste substances from all parts of the body and takes them to the organs which expel waste.

Sir William Harvey (1578–1657) who was physician to King Charles I, discovered that the blood circulates. Your teacher or public librarian may be able to get Harvey's book for you. Then you can read his own account of this important discovery.

The heart—a pump

The blood is pumped round the body by the heart. The heart lies in the chest between the lungs, slightly to the left side. It is about as big as your fist. The walls of the heart are made of a special kind of muscle which is found nowhere else in the body. This cardiac muscle never stops working. All day and all night, right through life, it contracts and relaxes steadily seventy times or more every minute. Runners usually have a slower heart rate, perhaps fifty to sixty times a minute. The heart does a great deal of work in driving the blood round the body.

Small animals have a high heart rate, large ones have a low heart rate. The elephant's heart is said to beat only twenty-five times a minute.



Heart cut from top to bottom

The heart is divided into a right and a left half. The blood in one half cannot mix with the blood in the other half. The thin walled upper part of each half is called an auricle. The lower part has a thicker wall and is called the ventricle. The opening leading from an auricle to a ventricle is controlled by valves.

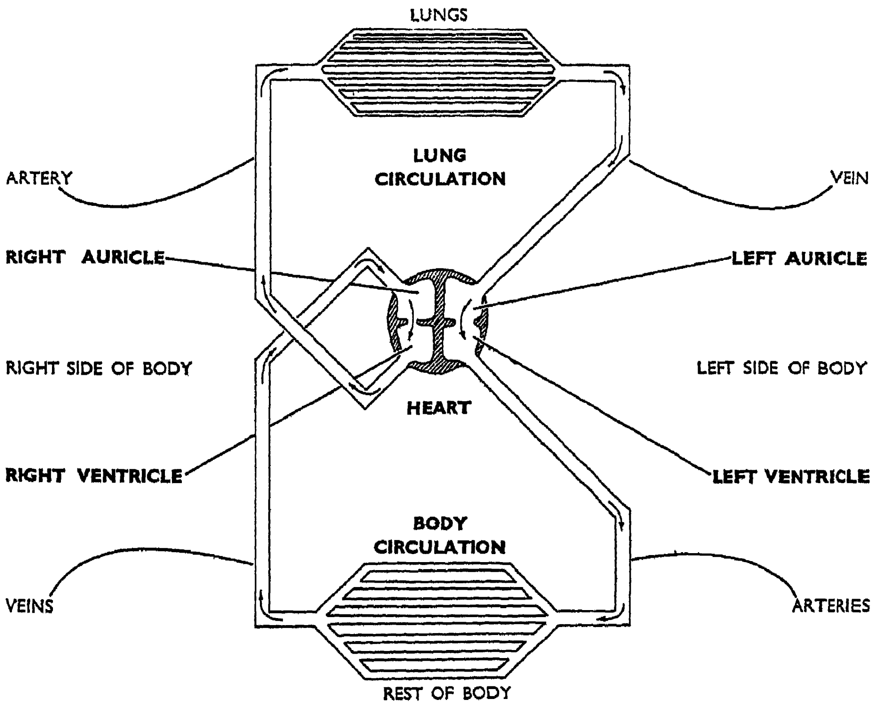
The blood-vessels

Blood travels round the body in tubes called vessels. Those vessels which carry blood towards the heart are called veins. Those which carry blood away from the

heart are called arteries. This is the main difference between the two kinds of vessel. Another difference is that veins have thin muscular walls and arteries have thick muscular walls. The finest branches, connecting veins and arteries, are capillaries. This name means "like a hair." The walls of blood capillaries are very thin. Liquids and gases pass into the blood or out of it to the cells of the body through the thin walls of the capillaries.

Circulation of the blood

Every drop of blood passes twice through the heart during one complete journey through the body. It passes once through the left side and once through the right side.



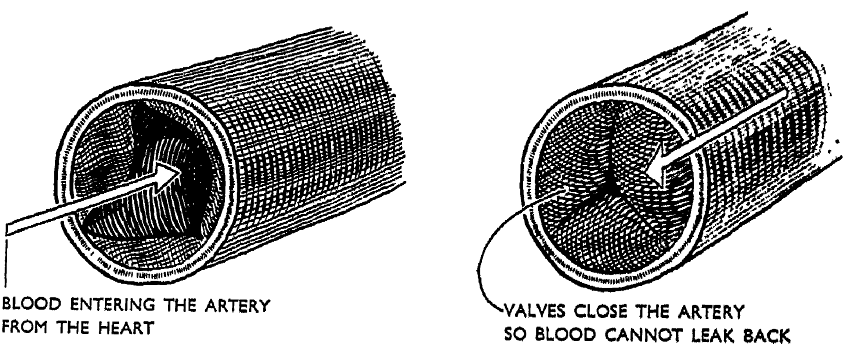
Blood comes into the left auricle of the heart from the lungs where it has picked up oxygen. As the blood is coming *to* the heart, the blood vessel through which it is passing is a vein. Because it comes from the lungs to the heart, the vessel is called the pulmonary vein. Then the auricle contracts and sends the blood into the ventricle below. The valves close the passage from the auricle and as the thick muscular walls of the left ventricle contract, blood is forced out of the heart along the main artery of the body (the aorta). The pumping action of the left side of the heart is great enough to send the blood all round the body.

When the blood has travelled round the body it returns to the right side of the heart. From the right auricle it passes down to the ventricle, which pumps it to the lungs. From the lungs it goes once more to the left auricle.

The heart beat is a double beat. It sounds like "lubb-dup."

The valves of the heart and the heart beat

(*a*) *Between auricles and ventricles* are valves made up of triangular flaps of tissue. As the ventricles fill with blood, the flaps float upwards. When the ventricles are



full of blood, the valves close the passage between the upper and lower parts of the heart. The first part of the heart beat, "lubb," is the sound made when these valves close and the muscles of the ventricles contract.

(*b*) *At the base of the pulmonary artery and the aorta* are three "watch pocket valves." The ventricle pumps blood out of the heart through these arteries. The valves close and prevent blood from leaking back to the heart. The second part of the heart beat, "dup" is the sound made when these valves close.

The pulse

As the heart pumps blood along the arteries the blood flows in jerks. Where an artery lies on a bone, as in your wrist, you can feel the jerky flow of the blood along the artery. A nurse measures her patient's pulse beat because it tells her something about how the heart is pumping blood.

Stopping bleeding

Blood in the arteries is under pressure from the heart. If an artery is cut, the blood spurts and bleeding is difficult to stop. At several points in the body, arteries pass over bones. If we press on these "pressure points" we can often stop the bleeding. We need to press on the point nearest to the cut and between the cut and the heart. A First Aid book will show you where to find these pressure points. It is important to know where to find them, because a person with a cut artery can lose blood very quickly, and may even die before a doctor can come to his aid.

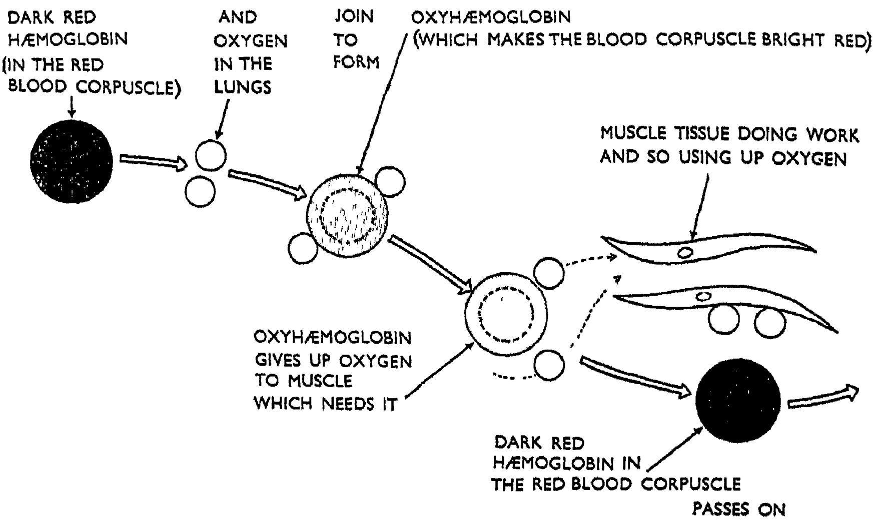
When a vein is cut, the blood flows smoothly. Bleeding

from a vein can often be stopped by pressing a thick pad of soft material over the wound.

What the blood is made of

Although the blood looks red, under the microscope we can see that it is really a straw coloured liquid in which float very many red cells and some white cells. These cells are called corpuscles. The liquid is blood plasma.

The red corpuscles are shaped like round biscuits. They



contain a dark red substance, haemoglobin. Haemoglobin has an important property. Whenever it meets oxygen, it joins with it and forms bright red oxyhaemoglobin. When this oxygenated blood reaches cells of the body that need oxygen, the red corpuscles give up their oxygen and become darker red again. There are 500 times as many red corpuscles as white ones in the blood.

Red corpuscles are made in the red marrow of some of the bones.

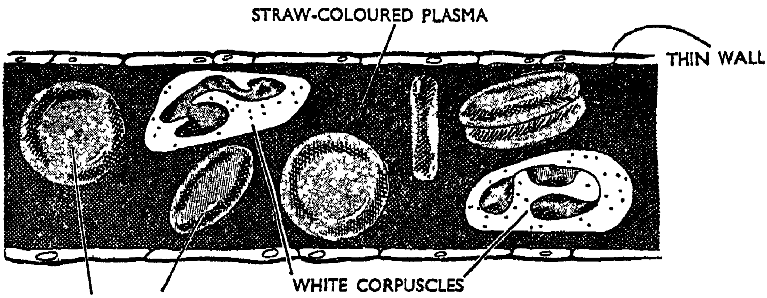
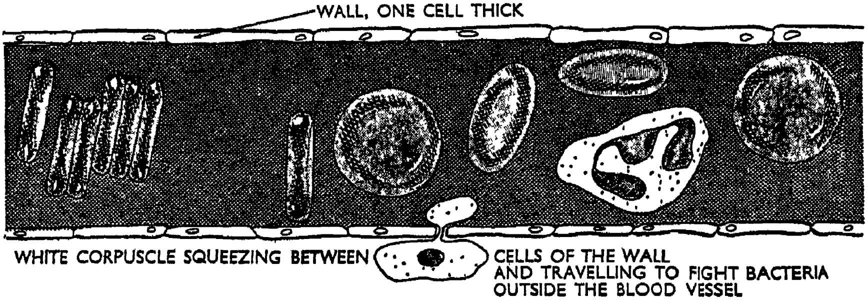


Diagram of blood in a capillary

The white corpuscles are bigger than the red ones. They can change their shape and can squeeze through the thin wall of the capillary and travel to the cells. They are the body's second line of defence. They destroy any bacteria which manage to pass the first line of defence, the skin.

Some of the white corpuscles can digest disease bacteria. Others make substances called antitoxins which counteract the poisonous liquids (toxins) made by disease bacteria. White corpuscles are made in the spleen, an organ which lies behind the stomach, and in red bone marrow.



The plasma contains digested food and water. It can pass through the capillary walls and travel to the cells nearby taking food and water to them. Then it passes through the walls of a colourless lymph tube and is carried in larger lymph tubes to the neck, where it returns to a large vein.

Substances carried by the blood

The blood carries:

1. Oxygen from the lungs to all parts of the body.
2. Carbon dioxide from all living cells to the lungs (Chapter 6).
3. Digested food and water from the digestive system (Chapter 4).
4. Waste liquid from all living cells to the kidneys (Chapter 5).
5. Chemical messengers from one organ to another.

Blood Transfusions are given in hospitals to patients who need extra blood or to people who have lost blood in an accident. Blood given to a patient must be of a type which will mix with his own.

LOOKING AFTER THE BODY

The body has a very delicate complicated structure. To keep it healthy we need:

1. Good food.
2. Fresh air and exercise.
3. Enough sleep. The body cannot work well if we are tired. We also catch diseases more easily when we are tired.

4. Interesting work and interesting hobbies.
5. To keep the body clean.
6. To visit the doctor promptly if anything goes wrong.

SOME WORDS USED IN TALKING ABOUT PARTS OF THE BODY

Word	*Meaning*
Gastric	Belonging to the Stomach
Cardiac	Belonging to the Heart
Pulmonary	Belonging to the Lungs
Renal	Belonging to the Kidney
Hepatic	Belonging to the Liver

QUESTIONS TO ANSWER

1. What is a tissue?
2. What are the uses of the skeleton?
3. What do we need in order to have good health?
4. Name two defences against disease.
5. What is the work of the heart?
6. Make a list of differences between arteries and veins.
7. What substances are carried by the blood?
8. Name the parts of the skin.
9. What is the work of the nervous system?
10. Trace the circulation of the blood from your left arm, round the body and back to the arm again.

THINGS TO DO

1. Study the drawing of the skeleton on page 24. Try to find the position of the bones in your body.

2. Find some of the movable joints in your body and make sketches to show the way in which they move.

3. Collect rabbit bones after a meal and clean them up with hot soapy water and a penknife. Try to discover which part of the rabbit's body each bone comes from. Examine the bones carefully. They are very much like our own in shape.

4. Try to sort the rabbit's vertebrae into four sets.

(*a*) Those which have two small holes, one on each side of the large central hole. These are from the neck region.

(*b*) Those with a long spine and small surfaces on each side to which the ribs are attached. These are from the back of the chest.

(*c*) The sturdiest ones have two spines from the top and two from the bottom. These are from the loin region.

(*d*) The three vertebrae which fit together to form a triangle. These are from the hip region.

5. If you can obtain the first two vertebrae (atlas and axis), and also a rabbit's skull, try to discover how the head moves.

6. Carry out the knee jerk experiment on page 26.

7. Soap is a chemical compound of a fat and an alkali. A good soap should not have much free alkali because alkali irritates the skin. Test different soaps to see if they contain free alkali. Weigh out five grams of each kind of soap, soapless detergent or washing powder you wish to test. Dissolve each in 500 cc. of distilled or rain water. Put 50 cc. of each in turn into a measuring cylinder. See how many drops of an indicator, phenolphthalein, you need add to turn the mixture faintly pink. A washing powder may contain a lot of free alkali as this helps in cleaning dirty clothes. Wash the measuring cylinder well after each test. (The solution which needs most drops contains least free alkali.)

8. Take two limb bones of a rabbit. Leave one in dilute hydrochloric acid for a day or two. Wash it and compare with the other bone. The acid has dissolved out the mineral salts which made the bone strong and firm. See if you can tie it in a knot.

9. Heat a bone strongly on a tin lid. The softer part burns away and mineral salts are left.

10. Examine under the microscope a drop of blood diluted with 1 per cent salt solution. Use the high-power objective.

11. Make a model of the human skin in coloured plasticene or with layers of coloured paper, copying the drawing on page 27.

12. Put a little oil or glycerine on your finger just below the nail. Look at this spot of skin with the low power of the microscope. You may be able to see some blood capillaries. What shape do they seem to be under the nail?

13. In January, when you hatch trout eggs in school examine a very young trout under the low power of the microscope. You will see the blood circulating in the capillaries of the yolk sac.

14. Read about controlling bleeding in a First Aid book. Find your own pressure points and copy a diagram of them.

15. Try to see microscope slides showing muscle cells and cells from other tissues. You may like to cut a very thin slice of the softened rabbit bone and look at it under the microscope.

CHAPTER 3

Our Food and its Uses

IF YOU MAKE a list of all the interesting foods you enjoy, you will find that they can be grouped into five main classes.

For example:

(*a*) *Starchy foods:* Bread, potatoes.

(*b*) *Sugary foods:* Fruit, sugar.

(*c*) *Fatty foods:* Butter, bacon.

(*d*) *Protein foods:* Eggs, lean meat, nuts.

(*e*) *Fresh green vegetables:* Salads.

Starch, sugar and fats give us energy.
Protein helps growth and repairs worn out cells.

A balanced diet contains all these classes of food. It also contains water, mineral salts such as cooking salt, and vitamins. Vitamins help us make the best use of food and help to keep the body healthy. If we have a lot of different things to eat, including fresh fruit and vegetables, we shall probably get enough salts and vitamins, but if we lived on fish and chips or bread and jam we should not get enough of these substances. The people of India and China who live chiefly on rice, sometimes develop a skin disease due to lack of one of these vitamins.

TESTS FOR STARCH, SUGAR, FAT AND PROTEIN

In Book I we learned that iodine solution turns starch black. If we obtain a black or dark blue colour when iodine solution is put on any food, we know that it contains starch. (It is sometimes necessary to remove the colour from a food before testing it. The green colour of leaves can be dissolved out by soaking the leaves in methylated spirit.)

We can usually tell if a food contains much sugar because it tastes sweet directly we put it into the mouth. There are also chemical tests to perform if we want to make sure. If we heat a little of the water in which food has been soaked with Fehling's solution, we obtain a green, yellow or red colour if certain kinds of sugar are present. A green colour means a little sugar, a red colour means that there is a good deal of sugar. You will find instructions for carrying out this test on page 47.

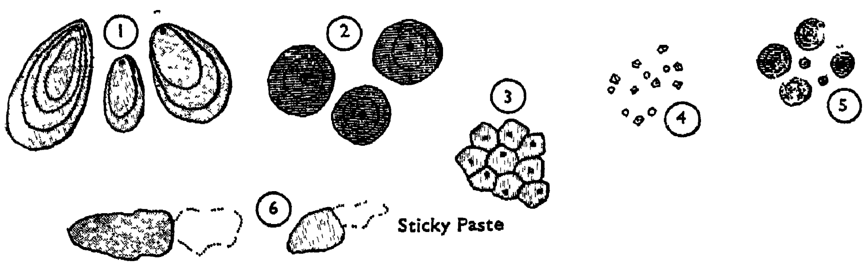
If we press some food containing fat on a piece of filter paper a greasy mark remains after the paper is dry. If we boil a little food cut into small pieces, with Millon's reagent, the pieces usually turn brick red if the food contains protein.

FOOD AND COOKING

Cooking starch. Starchy foods contain small starch grains. When cooked, the grains burst and are more easily digested. All starchy food except liver comes from plants and some plants have starch grains which are different in shape and size from all other kinds of starch grain. Some of them are shown on the next page, very highly magnified.

Cooking protein. Lean meat and fish are valuable body-building foods because they contain much protein, but

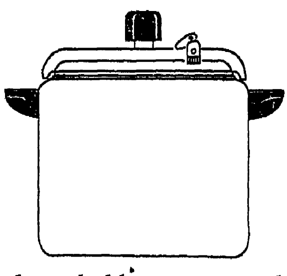
they are made of muscle cells which are tough. Cooking softens the muscle cells and also improves the flavour. Eggs contain a large amount of protein. Cooking solidifies



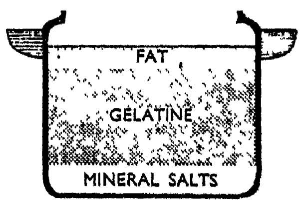
1. Potato starch 2. Bean starch 3. Maize starch
4. Rice starch 5. Wheat starch 6. Cooked potato starch

the liquid protein. This also happens when we bake a joint. The hard crust which forms on the outside is liquid protein which has set hard. So is the "skin" which forms on a baked milk pudding or on milk which has been boiled.

Pressure cooking. If we boil water in a strong sealed pan the steam will be trapped and will exert extra pressure on



A household pressure cooker



The result of pressure cooking bones

the boiling water. When this happens, the water boils at a higher temperature than 100° C. and so food will cook more quickly. When bones and animal skin are boiled at

high pressures they break up into fat, gelatine and mineral salts. The gelatine solution is made into glue.

Cooking on high mountains. The higher we climb above sea level, the lower is the pressure of the air around us. At pressures lower than normal air pressure, water boils at temperatures lower than 100° C. or 212° F. Even on Mount Snowdon the temperature of boiling water is not high enough to make a good cup of tea! On Mount Everest (over five miles high) it is impossible to make tea or to cook an egg because water boils before it is hot enough to brew tea or to set the egg.

Baking. We can heat an oven to a temperature of 490° F., a much higher temperature than that of boiling water. Regulators on gas and electric stoves enable us to set the oven at the temperature required and keep it there. These regulators are called thermostats.

Cooking in fat enables us to cook food quickly. The temperature of boiling fat is much higher than that of boiling water. Food cooked in fat is less digestible than food cooked in other ways.

Latent heat. Until the boiling point of water is reached, all the heat supplied to the water is used to raise its temperature. Once the boiling point has been reached, the temperature of the water remains constant. Any more heat supplied to the water is used to turn the water into steam. This extra heat is stored up in the steam. When steam at 100° C. turns to water at 100° C. every gram of steam gives out 540 heat units. This stored-up heat is called the hidden or "latent" heat of steam. You will understand now why steam burns are so painful and so dangerous. The heat set free from the steam onto your skin may badly injure the skin and the tissues under it.

FOOD AND ENERGY

Calories. We measure the energy set free from food by a unit of heat called a Calorie. It is the amount of heat needed to raise the temperature of one litre or one and three quarter pints of water through one centigrade degree (see Book I). Heat is a form of energy. Scientists have found the amount of energy produced by equal weights of each kind of food.

Fat has the highest calorie value. Sugar and starch have a calorie value of less than half this amount.

Some energy foods. Bread, potato, chocolate, sugar, butter, dripping, margarine, lard, cooking fat, suet, olive oil.

Some foods which help growth and repair worn out tissues. Cheese, eggs, lean meat, fish, milk, nuts.

Calories needed every day by members of our family

People doing heavy work need more energy foods than office workers. Adults need more than young children. Here are some figures.

Heavy worker	about 4,000 calories
Office worker	about 2,500 calories
Woman	about 2,500 to 3,000 calories
Boy (14 years)	about 3,000 calories
Girl (14 years)	about 2,600 calories
Young child (1 year)	about 1,000 calories

VITAMINS

Vitamins are substances which help us make the best use of our food. We need very small quantities of vitamins every day. Here are some of them:

Vitamin	*Found in*	*Use in the body*	*Destroyed by*
A	Butter, milk, fish liver oils. Orange and green vegetables	Helps general health, especially of the eyes	
B	Whole wheat grain, yeast, bacon, liver, meat, milk, eggs	Helps set free energy from starch and sugar. Keeps the nervous system healthy	Canning food
C	Cabbage, cauliflower, spinach, black currants, oranges, grapefruit, lemons, tomatoes, potatoes	Improves the health of the whole body, especially of the skin	Keeping vegetables and fruit too long Too much cooking, Cooking with soda. or in an open pan

(This vitamin dissolves in water, so greens should be cooked in as little water as possible.)

D	Fish liver oils, fish, eggs, butter, milk, cheese, liver	Helps to build strong bones and teeth. Enables the body to use calcium and phosphorus. Prevents rickets in children	

(This vitamin dissolves in fat or oil. Sunlight causes it to form in our skin.)

MILK

Milk is a perfect food because it contains:—

Water, fat, milk sugar, protein, mineral salts including calcium phosphate which contains calcium and phosphorus (this mineral salt helps to make bones and also tones up the body), and vitamins A, B, and D.

You will notice that both energy giving foods and body building foods are contained in milk, as well as mineral salts, vitamins and water. Milk is therefore a balanced food.

Babies can obtain all their food from milk. Nowadays,

however, even young babies are given in addition orange juice, containing vitamin C, and cod-liver oil, containing extra vitamins A and D. These extra vitamins help to make the best use of the foods in milk. For example, the mineral salt calcium phosphate cannot be used by the body unless enough vitamin D is present. So a child without enough vitamin D may have weak bones and poor teeth.

Not only babies, but people of all ages could live entirely on milk but they would have to drink rather a lot and would find their meals uninteresting. Since young people in this country have been encouraged to drink more milk, doctors find that they are taller, sturdier and generally more healthy than were young people of the same age before milk was provided regularly at school. On page 49 you will find some experiments which will help you to find out more about milk.

A human baby cannot digest cow's milk as easily as it digests human milk because cow's milk contains more protein and fat than human milk. Cow's milk also contains less sugar, and hardly any iron salts.

TEN QUESTIONS

1. For what purposes do we need food?
2. How would you test a carrot for starch, sugar, fat and protein?
3. Say what you know about vitamins.
4. Why is milk a perfect food?
5. Give two reasons why we cook food.
6. Why does tea made on top of Mt. Snowdon taste weak?
7. How does a pressure cooker cook food quickly?
8. Why is a steam burn more dangerous than a burn caused by boiling water?

9. Name the unit of energy set free from food.

10. What kinds of food would you give to a man who does heavy work?

WORK TO BE DONE

1. Test as many foods as you can for starch.

2. Cut some apple into small pieces. Cover it with a little water in a small beaker and leave it to soak for about 15 minutes. Pour the liquid (extract) into another small beaker. You should not have more than $\frac{1}{4}$ in. of extract in the beaker. Now add from a test tube $\frac{1}{2}$ in. of Fehling's solution A and $\frac{1}{2}$ in. of Fehling's solution B. Heat the beaker over a wire gauze mat on a tripod stand. If one type of sugar is present (glucose is an example) the blue solution will become muddy. Stop heating as soon as the liquid begins to boil.

If you obtain a red colour, much sugar is present. Yellow means that you have not quite as much. Green means that you have a little sugar. If the solution remains clear and blue, no sugar of this kind is present.

Note. Glucose or grape sugar is found in many fruits. It can remove oxygen from an alkaline solution of copper sulphate. Because we call the removal of oxygen from a compound reduction, we call sugars like glucose reducing sugars.

3. Unfortunately the sugar we use most often at home, cane sugar, is not a reducing sugar and so unless we rely on the tasting test, we may not detect it. There is a more difficult test which you may like to try. If you have obtained no result from the first test, boil a little extract with a few drops of dilute sulphuric acid for two minutes. Then neutralise the excess acid with caustic soda (see page 19, No. 10). Now add Fehling's solution and heat. If this time you do obtain the red, yellow or green colour, you will know that a sugar like cane sugar is present in the food you are testing.

4. Carry out the test for fats on as many foods as you can (see page 41). Which foods do you think contain most fat?

5. Test a number of foods for protein. Cut up the food into very small pieces. Put them into a test tube, cover with Millon's reagent and boil. If some kinds of protein are present, the food will turn brick red.

Your teacher may show you another test for protein. If he drops a little concentrated nitric acid on the food and the food turns yellow, protein is present. If he accidentally gets some of the acid fumes on his hand, that will turn yellow also. What does that tell you about the human skin? (Do not use concentrated nitric acid yourself.)

6. Make a table of all the foods tested by your class and show which food substances each contains. For example:

Food	*Starch*	*Sugar*	*Fat*	*Protein*
Potato (*a*) Middle	Much	None	None	Little
(*b*) Just below the skin	Much	None	None	Much
A green cooking apple	Much	Little	None	Little
An eating apple	None	Much	None	Little

7. Test some seeds for food substances. Keep some in damp sawdust until they have started to grow, then test again. What differences do you find?

8. Test the food substances in a sprouting potato. Compare your results with those from a potato which has not sprouted. What have you discovered about sprouting potatoes and germinating seeds?

9. Heat a little water in a round bottomed flask. When the water boils, remove the burner and seal the flask with a rubber bung. Invert the flask under cold water from the tap. The cold water condenses the steam and the pressure on the water is less than it was. The water boils. Turn off the tap and put your hand round the flask. The water will begin to boil again at a temperature not higher than that of your hand.

10. Try to see the Gas Board's film *The Obedient Flame* which shows clearly how the thermostat in a gas cooker works.

11. Test milk for starch, sugar, fat and protein. Which of these foods is not present?

12. Add a little dilute acid (vinegar, lemon juice or dilute hydrochloric acid) to milk. Notice that the acid curdles it.

13. Warm a little milk and add a few drops of rennet. The rennet sets the protein in the milk to junket. Shake the junket. The protein forms curds and the liquid whey separates. What food substances will be in the whey?

14. Examine some milk which has curdled after being kept for a few days. Harmless bacteria in the milk curdle it as the acid did because they turn milk sugar into lactic acid. Strain the curds through muslin and hang for a few days. You will have made cream cheese.

CHAPTER 4

How We Digest Food

THE FOOD we eat must be changed into liquid form before it can be carried round the body. The changing and dissolving of food is digestion. Digestion takes place in the digestive system, which is a tube about 30 feet long. One part of the tube, the stomach, is wider than the rest and forms a bag in which food can rest for a few hours.

You know that bits of meat and vegetables will not dissolve in water. The digestive system makes juices which can split up foods into simpler substances which dissolve in water. All our food must be split up by these juices before it can pass into the blood system and be carried to all parts of the body.

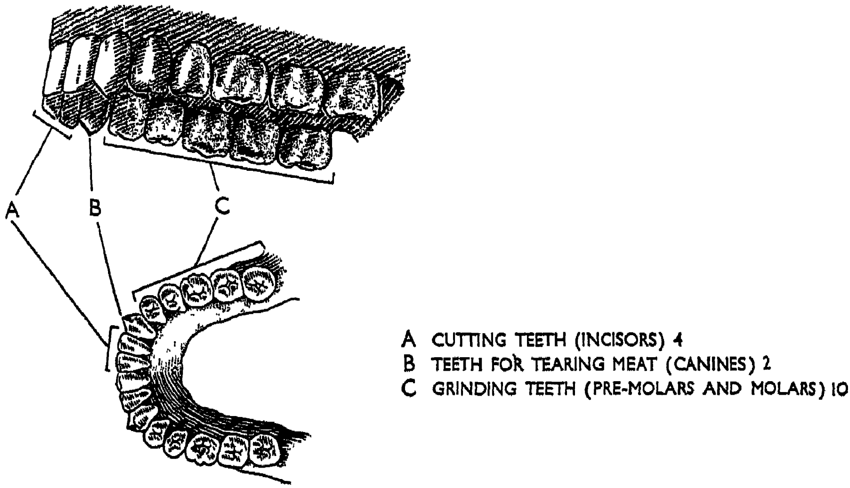
You can show that your mouth contains a juice, saliva, which changes starch to sugar. Chew a dry biscuit for half a minute. You will find that although at first the biscuit does not taste sweet, at the end of this time it will taste quite sweet.

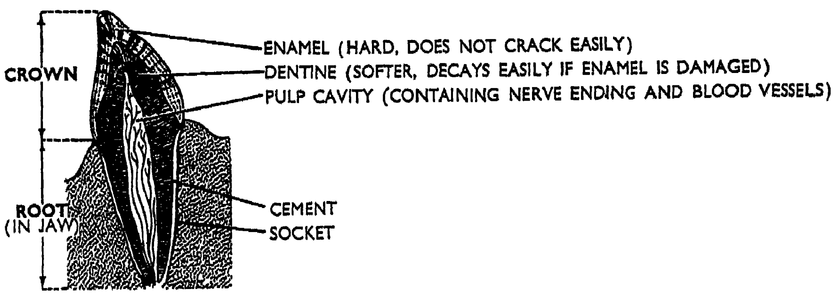
Suppose you have had for breakfast a cereal, an egg, brown buttered toast, and tea with milk and sugar in it. Let us look at a diagram of the digestive system and trace the path the food will take as it is digested. Before we do this, however, we should find out about our teeth, because it is they that prepare the food for digestion.

TEETH

Young children have a temporary set of milk teeth. Between about 6 and 11 years these temporary teeth drop

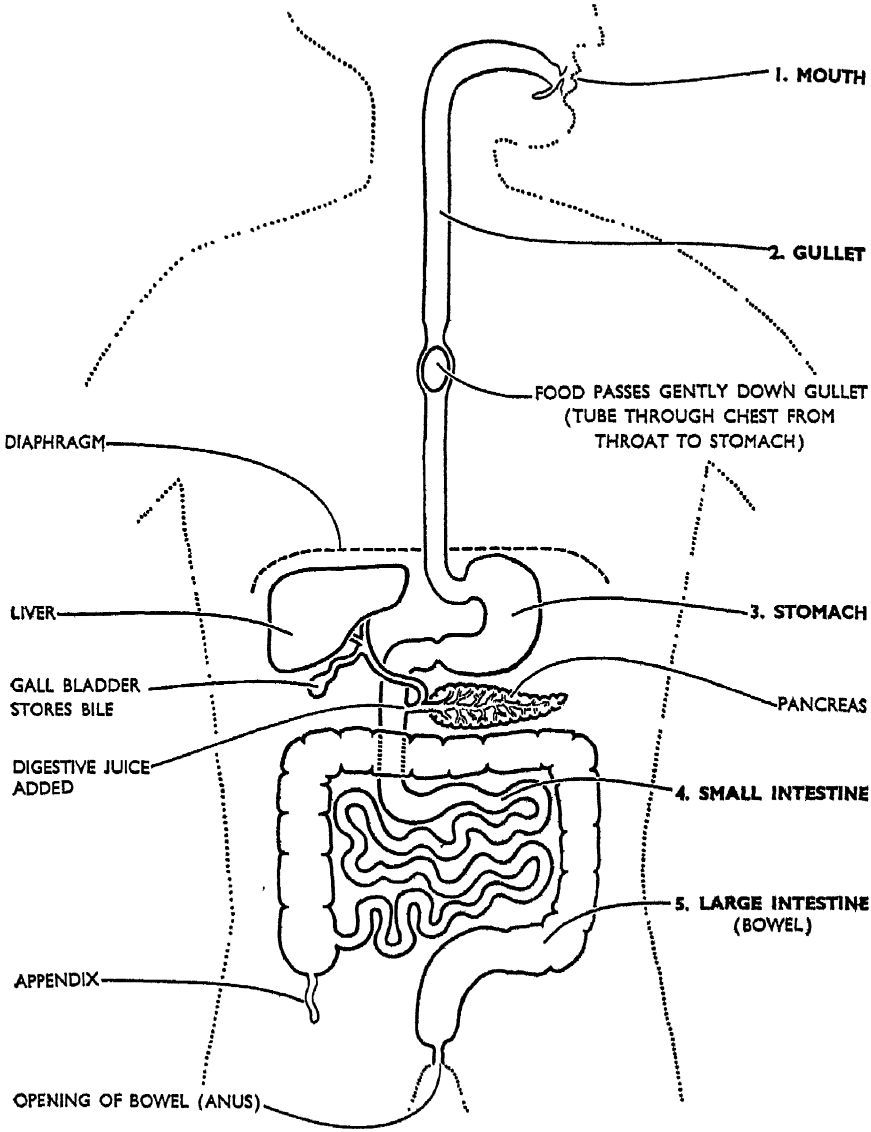
out and are replaced by permanent teeth. An adult has 32 teeth altogether. Find the four sharp cutting teeth in front of each jaw. On each side of them is a pointed tooth for tearing meat, and behind these are the double teeth which are used for grinding the food.





Structure of a canine tooth

If the enamel cracks, bacteria can rot the soft dentine



The human digestive system

Mastication in the mouth

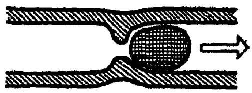
(*a*) Food is chewed by the teeth into tiny pieces.

(*b*) It is mixed with saliva. Some of the starch in the cereal and bread changes to sugar.

(*c*) The tongue rolls the food into a ball, and it is swallowed.

In the gullet

The gullet or food tube passes right through the chest. The muscles of the wall of the gullet gently squeeze the balls of food down to the stomach.



Muscles of the gullet wall contract just above the food ball. Then they relax as the layer lower down contracts. In this way, food is gently squeezed down the gullet to the stomach.

Digestion in the stomach (the stomach lies near the waist)

(*a*) Food entering the stomach may be mixed with germs. These are killed by hydrochloric acid made by the stomach wall.

(*b*) The cane sugar in the tea is changed into simpler sugars.

(*c*) A digestive juice, rennin, curdles the protein in milk. Rennin from the stomach of a sheep is known as rennet. We use it to set junket.

(*d*) Another digestive juice starts to split up the protein in the cereal, egg, bread and milk.

Digestion in the small intestine

Digestive juices from the liver and pancreas enter the small intestine through narrow tubes called ducts. These juices finish changing the starch and protein and also the fat in egg and milk. After passing along the small intestine all the food which can be used by the body has been dissolved. The bran in the bread and some parts of the cereal will not dissolve.

How digested food is absorbed into the blood stream

The lining of the small intestine is covered with projections which look like fingers. They absorb the digested food and pass it into the blood. The blood carries it to all

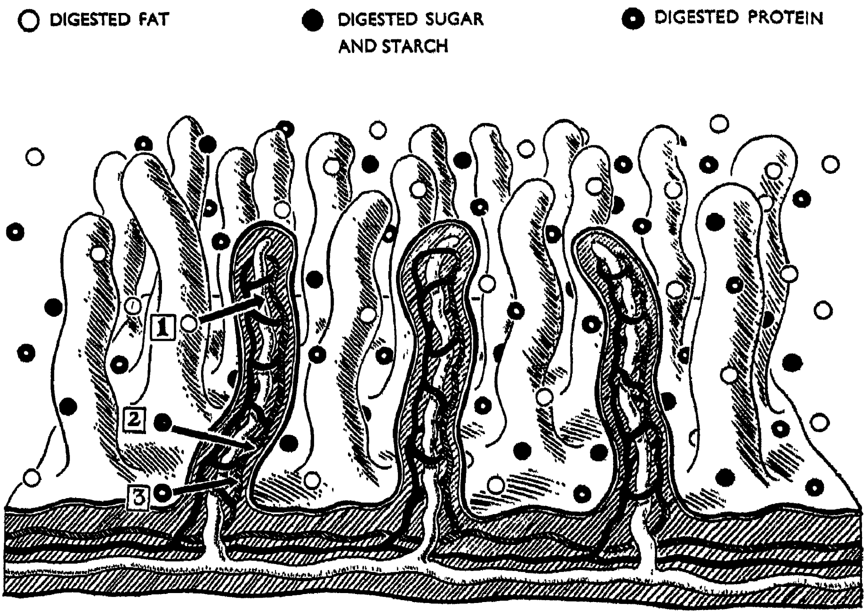


Diagram of a small piece of the small intestine, showing molecules of digested food

parts of the body. All the digested food except fat passes straight into the blood, but digested fats pass first into lymph tubes and travel up to the neck with the pale coloured fluid called lymph. In the neck, the lymph and the digested fat pass into the blood because it is in the neck that the lymph vessels meet large veins.

What happens to the undigested food

The undigested food passes from the small intestine to the large intestine or bowel. Water is withdrawn from the waste matter, which becomes solid. This is passed out of the bowel as faeces.

How digested food is used by the cells of the body

The digested food can pass through the walls of the blood vessels. Some of the liquid part of the blood (plasma) passes out with it and helps to spread the food over all the cells. When the food has passed into each cell, the energy foods join with oxygen and set free energy. The digested protein builds new protoplasm and so makes new body tissues.

What happens if we eat too much food. Excess of energy food is turned into fat and stored in the tissues. Excess protein food is got rid of with the waste liquid, urine.

Why we should eat brown bread, fruit and vegetables. These foods contain roughage, vitamins and mineral salts. Roughage is the outside of the wheat grain and parts of plant tissue which we cannot digest. It prevents constipation because it helps the muscles of the bowel to grip the waste material and expel it from the body.

The appendix is a short branch of the intestine. It is shaped like the finger of a glove and it seems to be useless to us, but it becomes inflamed and painful if hard grains

of food are trapped in it. If this happens, a surgeon may have to remove it. Some vegetarian animals, for example, the rabbit, use the appendix to digest hard parts of vegetables and tree bark.

THE LIVER AND ITS WORK

The liver is a large lobed organ just below the diaphragm.

1. *It makes bile*, a useful juice which helps to digest food. Bile is alkaline and so it will neutralize acid in the food coming from the stomach to the small intestine. It is stored in the gall bladder which is embedded in the liver, until it passes down the bile duct into the small intestine.

2. *It destroys worn out red corpuscles*. Red corpuscles contain iron which is very useful to the body. After about six weeks in the blood stream, red corpuscles are destroyed by the liver. The iron is extracted and is used for making more red corpuscles. The remains of the corpuscles pass into the bile, giving it a yellow colour.

3. *It controls the amount of sugar in the blood*. From the small intestine the blood takes sugar to the liver. The liver turns it into animal starch and stores it temporarily. As the blood sugar is used up by the cells of the body, the liver releases the correct amount of sugar into the blood.

4. It prepares excess protein food we have eaten, so that it can be removed from the body, by the kidneys.

QUESTIONS ON DIGESTION

1. What do we mean by digestion?
2. What is the work of digestive juices?

3. How many teeth has an adult? What is the use of each kind?

4. Name the parts of the digestive system.

5. What separates the chest from the abdomen?

6. What happens to food in each part of the digestive system?

7. What is roughage? What is its use?

8. How do muscles help to pass undigested material from the bowel? (The drawing on p. 53 will help you to answer this question.)

9. Say what you know about the appendix.

10. What is the work of the liver?

THINGS TO DO

Experiments on digestion (to be carried out under the direction of the Teacher)

1. *Test a dry biscuit with iodine solution*, and show that starch is present. Chew a similar biscuit many times. What has the saliva done to the starch?

2. *Touch a piece of mauve litmus paper with the tongue* moistened with saliva. Is there any change in colour? Is the saliva neutral, acid or alkaline to litmus? What happens to the litmus paper if you leave the saliva on it for ten minutes?

3. *To show that digestive juice from the stomach of an animal will change and dissolve protein.*

Put a little hard boiled white of egg into a test tube with a little of the digestive juice, pepsin solution and a few drops of dilute hydrochloric acid. Keep the tube in hot water in which you can comfortably hold a finger. Notice what happens to the egg protein. What happens to the protein if you omit the acid? If you omit the pepsin?

4. *To show that a digestive juice from the small intestine of an animal will change the fat in milk.*

Boil and cool a little fresh milk and make it mauve with litmus solution. Divide the milk between two test tubes. To one, add a

little of the digestive juice, lipase solution. Keep it warm as in the previous experiment. What happens to the colour of the litmus in the tube with digestive juice? What has this juice done to the fat in the milk?

(N.B.—Pepsin and lipase can be purchased in powder form from Messrs. Flatters & Garnett, 309 Oxford Road, Manchester.)

5. Demonstrate the passage of food down the gullet with a wide piece of thin walled rubber tubing and a small marble or large bead. Gently squeeze the tube just above the marble.

CHAPTER 5

How the Body gets rid of Waste

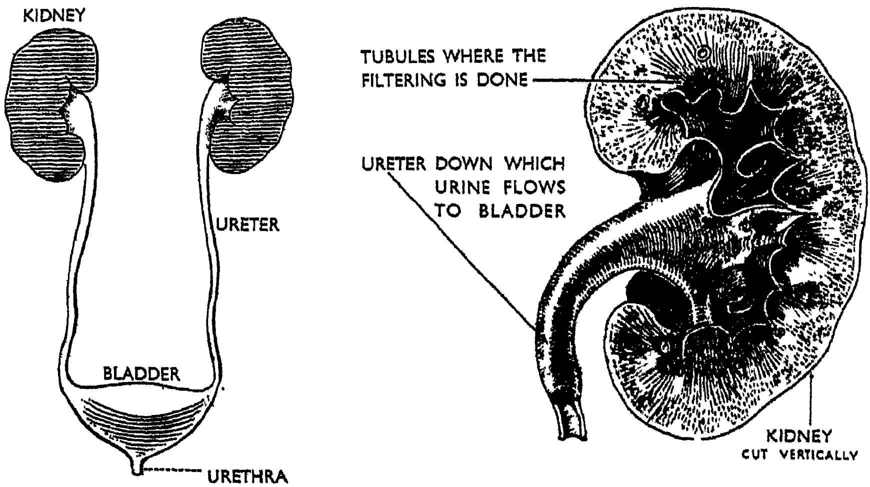
WE HAVE LEARNT that material which we cannot digest is passed out of the body from the digestive system. The process by which we get rid of it from the bowel is called defaecation. In this chapter you will learn how waste substances made in the body are got rid of by the kidneys, skin and lungs. The removing of waste substances made in the body is called excretion.

EXCRETION

All the time we are alive, the living protoplasm of the body is continually wearing out and new protoplasm is always being formed to replace it. The protein food we eat builds up new protoplasm. The worn out protoplasm breaks down into a watery liquid and passes into the blood stream. The blood carries it to the kidneys to be got rid of, or excreted, from the body. We cannot store protein in our bodies, so any excess of protein food which we cannot use immediately for growth or for replacing worn out protoplasm is also taken to the kidneys and excreted. If we have eaten more mineral salts than the body can use, the excess goes to the kidneys also. To wash these substances out of the cells of the body and to carry them away from the body we need to drink a good deal of water. When we are ill, drugs given by the doctor must be washed out of the body after they have done their work, so when we are ill, we have to drink plenty of water or fruit juice.

THE KIDNEYS AND THE WORK THEY DO

The kidneys are two oval organs attached to the loin region of the back. Blood containing waste substances is brought to each kidney by the renal artery. As the blood passes through the kidneys it is filtered. Valuable substances such as blood plasma, corpuscles and sugar, are kept in the blood; water in excess of the body's needs,



The kidney system showing one kidney cut lengthwise.

waste liquid and salts, are filtered off. After the blood has been filtered, it leaves the kidneys in the renal veins. The waste liquid which is filtered off from the blood by the kidneys is called urine. It passes slowly down two narrow tubes called ureters and is stored temporarily in a muscular bag, the bladder. From the bladder it is expelled from the body at intervals. It is most important that the kidneys filter all waste materials from the blood. When the kidneys are diseased and so are not working well, the waste material accumulates in the blood and poisons the living

cells of the body. If this continues, the patient becomes unconscious and dies.

Besides removing waste from the blood, the kidneys also keep the composition of the blood constant. This is very important. If some useful substances such as sugar accumulated in the blood, water would be sucked into the blood from the cells around the blood vessels. The body would become shrivelled and thin. The cells could not do their work because they would not contain enough water, and severe illness would result.

THE SKIN AND EXCRETION

Sweat or perspiration is waste liquid which is removed from the body by the skin. Near some of the tiny blood capillaries in the skin are coiled tubes called sweat glands. Some liquid passes from the blood in the capillaries into the sweat glands and leaves the body through the skin. When the body is overheated, more liquid is lost by perspiration and less is lost as urine from the kidneys. Miners lose a great deal of water, and also a lot of mineral salts, in perspiration. That is why they have to take salt water instead of ordinary drinking water while they are working at the coal face.

There is a drawing of a sweat gland on p. 27.

THE LUNGS AND EXCRETION

Waste carbon dioxide and some water vapour are excreted from the lungs every time we breathe out. You can "see your breath" on a cold day because the water vapour in it is cooled quickly and condenses to drops of water. In this condition it looks like mist.

TEN QUESTIONS ON EXCRETION

1. Name the parts of the body which get rid of waste.
2. What part of the body filters the waste from the blood?
3. Why must waste liquid be removed from the blood?
4. What would happen if the amount of sugar and salts in the blood were allowed to increase?
5. What is the work of sweat glands?
6. What do we mean by excretion?
7. What is excreted from the lungs?
8. Why do miners need to drink salt water?
9. Name a food which cannot be stored in the body.
10. How does the liver help us if we eat too much of this food?

THINGS TO DO

1. Look at a kidney from the butcher's shop. Find out which animal it came from. Cut it lengthwise and examine it carefully to see all its parts.

2. Make a drawing of the kidney system of a human being. Label all the parts.

CHAPTER 6

The Air and How We Use It

YOU WILL REMEMBER from Book One that the air around us is a mixture of gases. The oxygen in the air is important not only to human beings but to all living things because it is needed to set free energy from food. Only when the energy of food has been set free, is an animal or a plant able to do any work. We should die in a few minutes if we could not obtain air containing oxygen. If, in the future, human beings are able to visit the moon, they will need to take a supply of oxygen with them because the gases around the moon do not contain this gas.

We do not use carbon dioxide, but if there were none in the air around us, we should very soon die because green plants use it to make food (see Book One). Neither we nor the animals could live without the food made by plants.

HOW AIR ENTERS THE HUMAN BODY

The air around us is colder and drier than the cells inside the body. As air passes through the nostrils and nose it is warmed and moistened. The nose has a sticky, hairy lining. Dust and disease bacteria are trapped by this lining and so only clean warm air passes on down the windpipe to the lungs. For this reason you should always breathe through the nose.

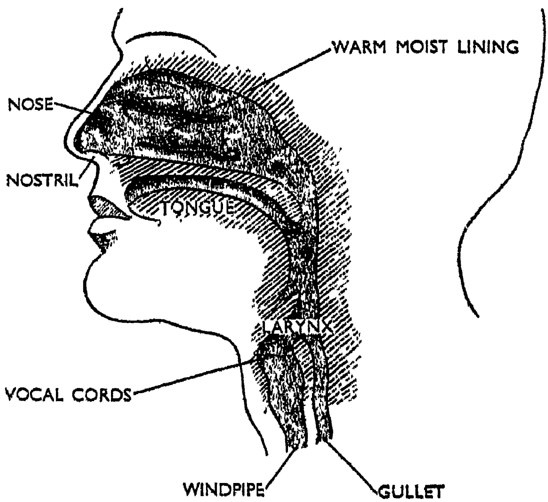
WHY ADENOIDS CAN BE HARMFUL

Adenoids are small structures in the nose. If they are

too large they block the nose and make you breathe through the mouth. This is bad because air containing dust and disease bacteria passes into the lungs and the cold dry air chills and dries their delicate lining.

THE WINDPIPE AND LARYNX

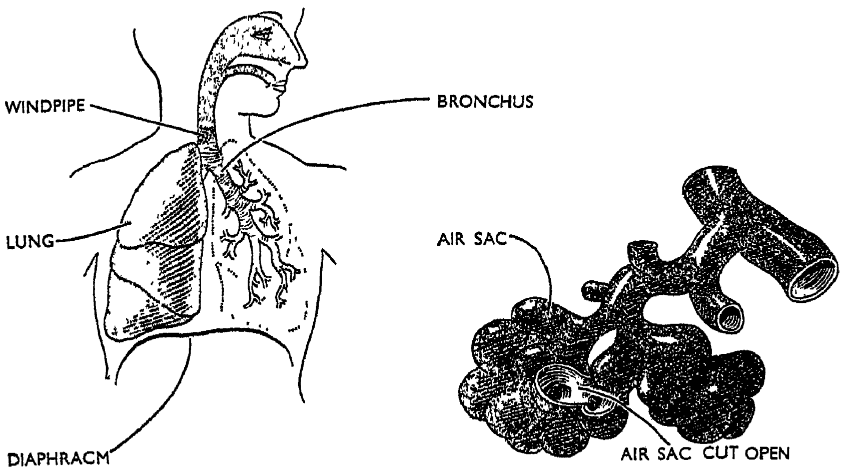
After passing through the nose, air travels down the windpipe. If you run a finger down your neck below your chin, you can feel the hoops of gristle (cartilage) which keep the pipe open. At the top of the windpipe is the voice box or larynx. Two strings which can vibrate, called vocal cords, are stretched across the opening at the top. The vibrations of these vocal cords enable us to speak.



THE LUNGS

The windpipe divides into two smaller tubes in the chest. Each tube leads to a bag with spongy walls. These

bags are the two lungs. Their walls contain many small blood vessels. The lungs lie one on each side of the heart. They are protected by a bony case made by the backbone, the ribs and the breastbone. If you examine some "lights" sold by the butcher for cats' food you will see how spongy lung tissue is. A small piece will float on water.

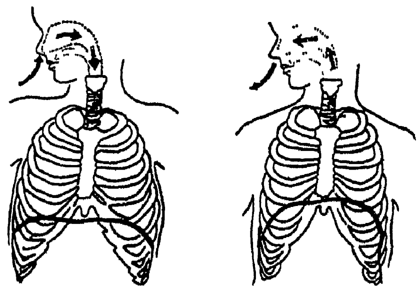


With a magnifying glass you will see many tiny air spaces in the wall of the lung. These small air spaces, each surrounded by a thin skin, are called air sacs.

How Air enters the Lungs. When we breathe in, the ribs swing upwards and outwards. The diaphragm below the lungs flattens. The space in the chest therefore increases. The lungs expand to fill it and air is drawn into the lungs from the atmosphere.

How Air leaves the Lungs. When we breathe out, the ribs swing downwards and inwards and the diaphragm

relaxes and returns to its curved position. Air is pressed out of the lungs.



Inspiration Expiration

HOW AIR IS CHANGED BY BREATHING

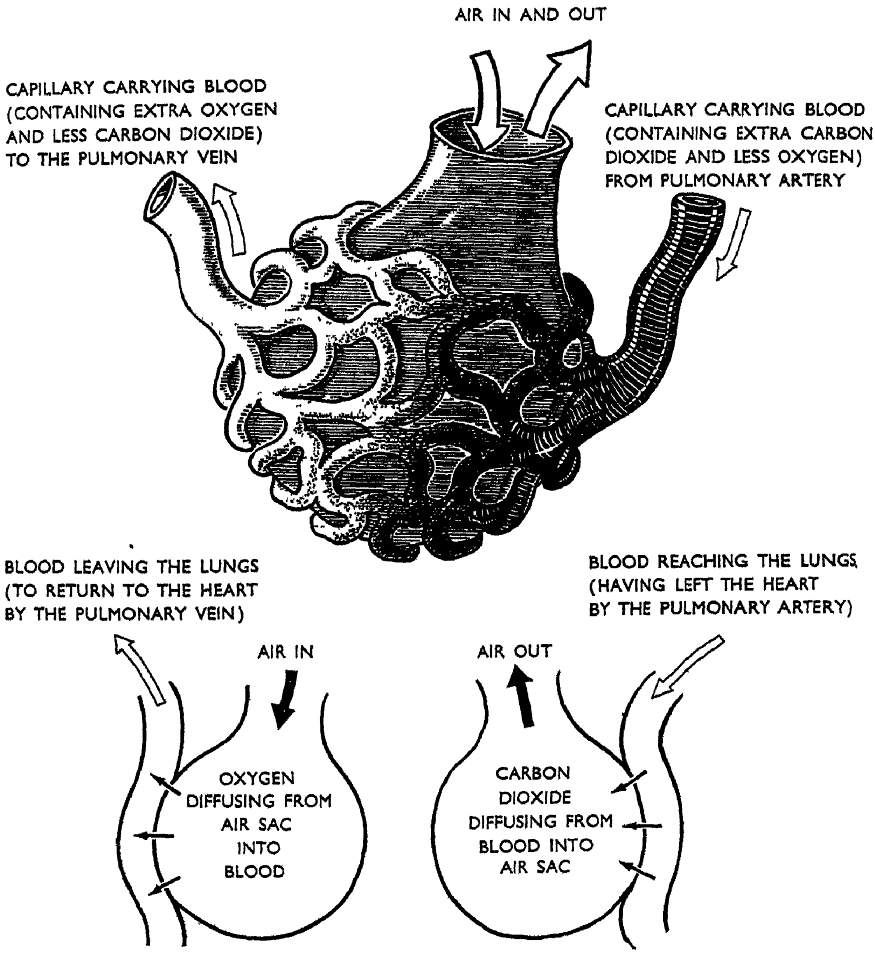
	Air breathed in	Air breathed out
Oxygen	20%	16%
Carbon dioxide ..	·03%	3%
Water vapour ..	varies	increased
Nitrogen	79%	79%

WHAT HAPPENS TO THE AIR IN THE LUNGS

The change in the composition of the air takes place in the air sacs. Here is a diagram of one air sac greatly enlarged, showing the very thin skin (much thinner than the skin of a grape) on which are blood capillaries.

When blood reaches the lungs it has given some of its oxygen and food to the body cells and has received in exchange waste materials including carbon dioxide and water. In the lungs, by the Law of Diffusion (Book One), oxygen will pass from the air in the air sacs to the blood, and carbon dioxide will pass from the blood into the air in the air sacs.

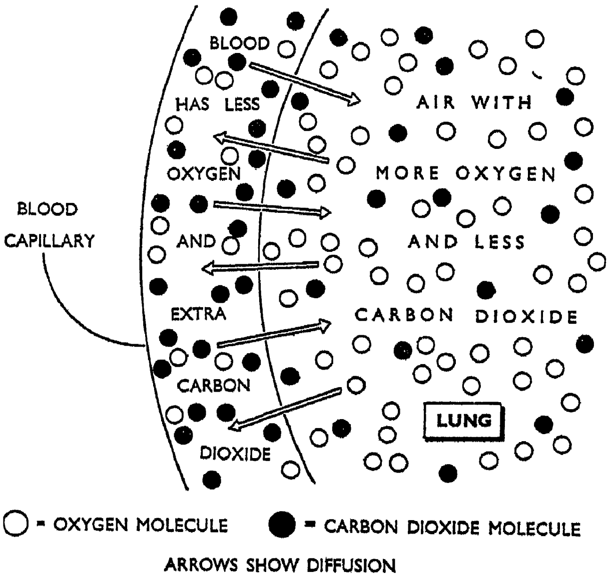
Breathing is the name given to the chest movements we can see and feel when air is taken into and pushed out of the lungs.



(*Above*) Outside view of an air sac

(*Below*) Section through an air sac
(*a*) *Breathing in* (*b*) *Breathing out*

Rate of breathing. When we need energy more quickly we breathe more quickly. In this way we obtain extra oxygen which is needed to set free energy from our food.



When we run, we breathe more quickly than when we are walking slowly. When we are resting in bed we breathe much more slowly than when we are very active.

RESPIRATION

The movements of the chest and lungs which we call breathing, only cause air to be taken into the body and expelled from it. From the lungs oxygen passes to all the cells of the body. There it joins with food containing stored energy and the energy is set free. *The setting free of energy which takes place in every living cell of the body all the time we are alive* is called by scientists respiration. Only some animals can breathe, but all animals and all

plants must respire because this is the only way they can obtain energy.

Respiration and burning. Respiration is rather like burning except that burning usually takes place at a high temperature while respiration can take place at the temperature of the human body or at much lower temperatures. It can only occur in living things.

In respiration. Oxygen joins with food and produces *energy* for movement, and also heat.

Waste products are carbon dioxide and water vapour.

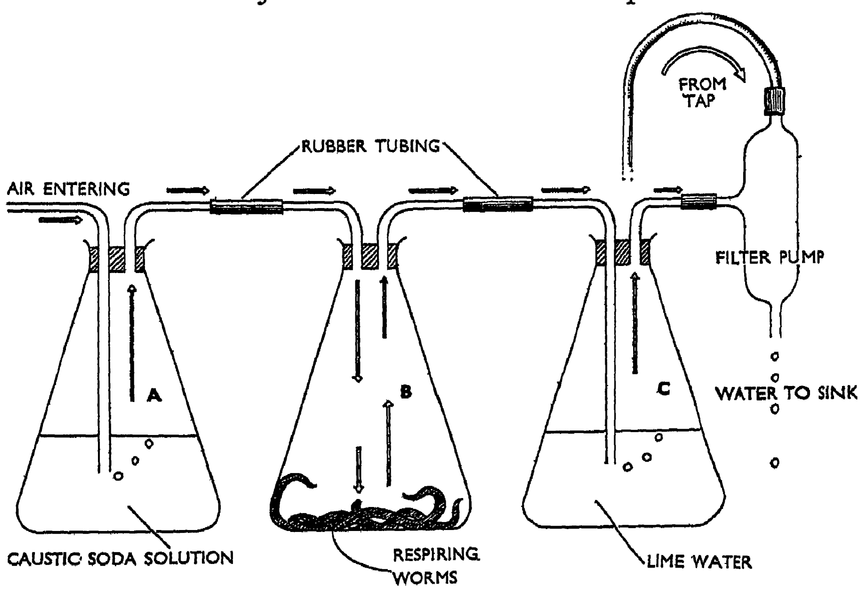
In burning coal or any other fuel, oxygen joins with the fuel and produces *energy* (heat and light).

Waste products are carbon dioxide and water vapour.

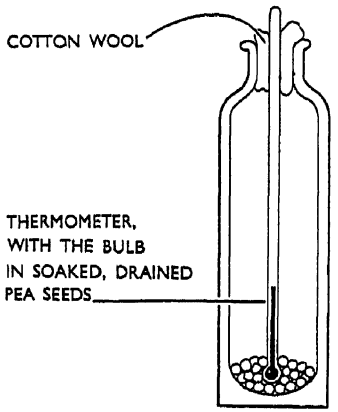
Food is the fuel needed by the body to obtain energy.

RESPIRATION IN ANIMALS AND PLANTS

The easiest way to find out whether a plant or animal



is respiring is to see if it gives out carbon dioxide. Carry out an experiment with the apparatus shown on p. 69 using two earthworms, and then using a plant. You may like to repeat it using germinating pea seeds. Cover the flask containing the earthworms with a dark cloth because these animals dislike light. Cover the flask with the green plant in it because you must not allow the plant to make food while you are performing this experiment. Can you think why?



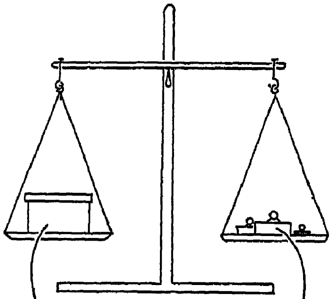
Section through a thermos flask

ENERGY IS GIVEN OUT DURING RESPIRATION

Have you noticed that snow often melts more quickly on plants in the garden than it does on the bare soil? It looks as if plants give out a little heat. Carry out this experiment and see what happens to the temperature of the air around the germinating pea seeds. Germinating pea seeds respire rapidly because they are beginning to grow quickly.

AN ANIMAL OR PLANT LOSES WEIGHT AS FOOD IS USED UP IN RESPIRATION

Try to carry out the experiment on the next page using a hamster, mouse, or any other small mammal which does not have sweat glands on its skin. (Can you think why this precaution is necessary?) Find how much weight is lost during one lesson. You will need a large balance.

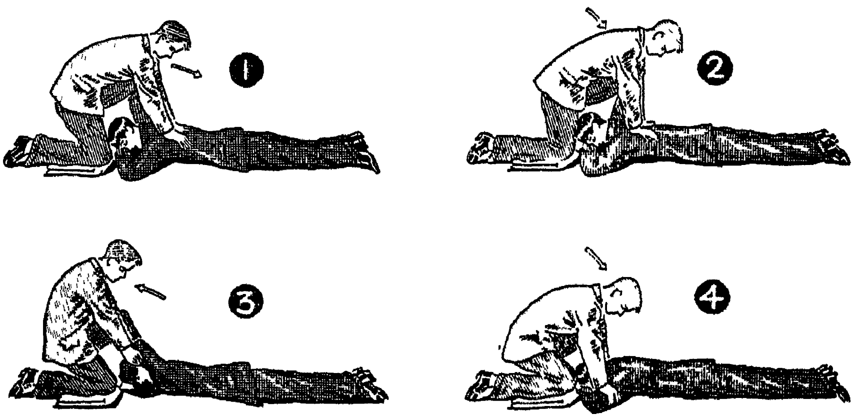


VENTILATION

All our rooms at home should have fresh air coming into them and the used air should be able to escape. Open windows let air in. It will circulate, become warmed, then leave the room through the top of the window and, if there is a fire, through the chimney. A badly ventilated room makes you feel drowsy and uncomfortable and can cause a headache. Correct ventilation should supply enough oxygen for the needs of people in the room and for the fire, but there should not be enough cold air entering to make the room cold. In some modern buildings a supply of warm air is circulated and kept moving inside the building. Some fresh air enters when doors are opened but the movement of air allows people to work in comfort. Fuel for heating the building is saved without damaging the health of the workers.

Good ventilation is as important at night as it is in the daytime, so windows should be kept open at night. Deep breathing ventilates the lungs and prevents stale air from collecting in them. It is a much more healthy habit than that of shallow breathing.

ARTIFICIAL RESPIRATION



The Holger Nielsen method of artificial respiration
Movements: 1, 2, 3, 4 until breathing is resumed, then 3, 4, 3, 4.

By the time a person is rescued from drowning, suffocating or choking, his natural breathing movements have sometimes stopped. He is given artificial respiration in order to start his breathing movements again.

USING OXYGEN IN HOSPITALS

People with certain lung diseases may sometimes need more oxygen than they can obtain from the air. Oxygen gas can be compressed and stored in cylinders. When a tap is turned on, the pressure is released and oxygen flows out of the steel cylinder. It can then be given to patients who have difficulty in breathing. If a large quantity of oxygen is needed, the patient may be placed in a tent into which oxygen is passed, or into an iron lung, which helps him to breathe.

TEN QUESTIONS ON AIR

1. Name the gases in the air.
2. Why do we need oxygen?
3. What happens to air as it passes through the nose?
4. What happens when we breathe in? When we breathe out?
5. Where is the diaphragm?
6. What happens to blood as it passes through the lungs?
7. What is breathing? What is respiration?
8. Do plants breathe? Do they respire?
9. Why is respiration like burning?
10. Why should we ventilate rooms well?

EXPERIMENTS TO DO OR TO WATCH

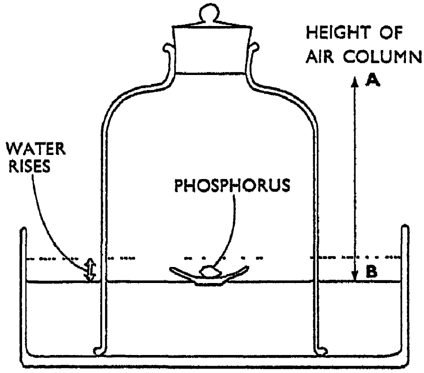
1. *A burning candle uses up part of the air.*

Fix a piece of candle on a cork and float it on water. Light the candle, cover with a small bell jar and watch what happens. What has the burning candle done to the air? Why do you think the candle went out?

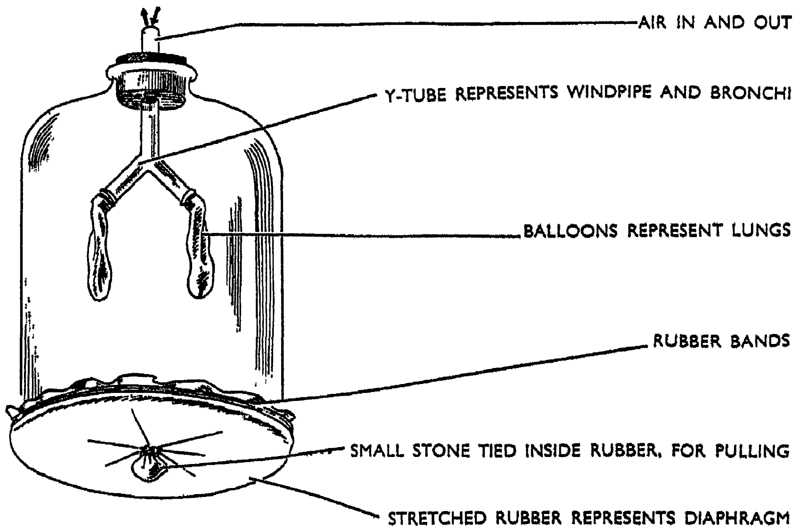
2. *To find how much of the air is used up when phosphorus burns.* DEMONSTRATION BY THE TEACHER. PHOSPHORUS MUST BE HANDLED WITH GREAT CARE AND ANY REMAINING IN THE BASIN AFTER THE EXPERIMENT MUST BE BURNED UP IN THE AIR BEFORE THE DISH IS WASHED.

Float a porcelain basin containing a little phosphorus on water in a glass trough. Place an unstoppered bell jar over the basin. Mark the level to which the water rises in the jar, and measure AB in inches. Light the phosphorus by touching it with a warm copper wire and immediately insert the stopper. When the flame is extinguished, allow to cool, pour water into the trough until the levels inside and outside the bell jar are equal, and

measure the height the water has risen. Then find the fraction of the air which has been used up.



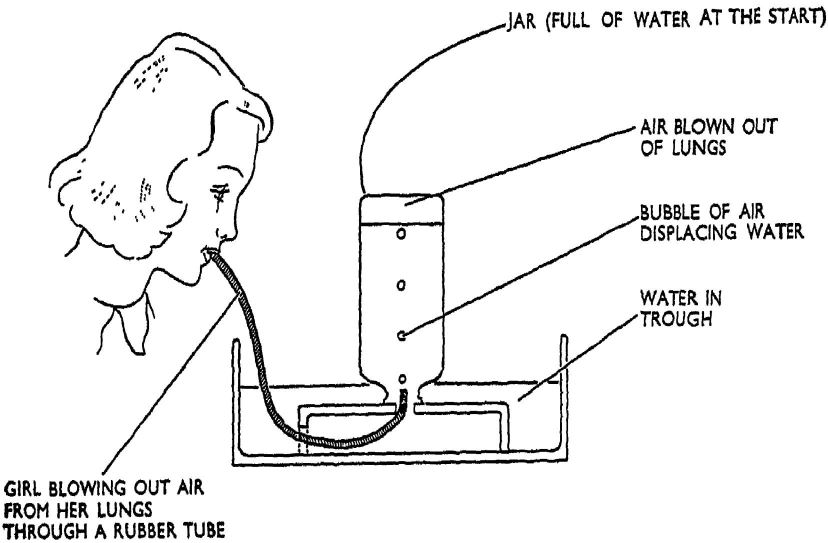
3. *Count how many breaths* you take in one minute sitting at your desk. Run round the playground, come back to your desk and count again. Can you say why the second result is different from the first?



The space inside the glass bell represents the chest cavity

4. *Make a model of the chest* to show how the lungs inflate and deflate. Pull down the rubber sheet, then push it up. Notice what happens and try to say why. (The sheeting should be very thin.)

5. *Find how much air the lungs can hold.*
Take a deep breath, then blow the air out of your lungs down the tube. The air displaces the water in the bottle. Remove the bottle and say how you would find how much air was in your lungs. (You may use any piece of apparatus to help you.) Refill the bottle and repeat the experiment after taking a shallow breath.



6. *Find where the ventilation currents of air occur in a room.*
Hold a 6 in. strand of thin knitting wool by one end in different parts of the room. Notice where the free end moves most. Try to say in what direction the air is moving, for example, from the window to the fireplace. Can you find others?

CHAPTER 7

The Body and Comfort

ALL SORTS OF THINGS make us feel uncomfortable. Pain is a discomfort which tells us that something is wrong inside the body. The most important things outside our bodies which affect our comfort are (1) temperature and humidity, (2) noise and (3) light.

TEMPERATURE AND THE BODY

When we run about we get hot. The use of our muscles has produced heat within our bodies. Even when we are not moving about, muscles, for example the heart muscles and breathing muscles, are always working and producing heat. We should expect this continuous production of heat to make the body temperature rise steadily, and yet we know it does not. The temperature of the human body is about 98.4° F. and if it rises much above that, we are ill. The temperature will remain constant when the body is losing the same amount of heat as the muscles are producing. When the body has to do extra work to keep its temperature constant we feel uncomfortable.

When we go into a place which is too hot the body has to do extra work to lose the heat which it is producing. The tiny blood capillaries under the surface of the skin get wider and more blood comes near to the surface to be cooled. We become flushed. We also perspire, and when the perspiration evaporates it helps to cool the body to its correct temperature.

When we go into a place which is too cold the body has to do extra work to stop its temperature from falling. The capillaries get narrower, the blood moves in away from the surface and we look white. There is very little perspiration and so no heat is wasted evaporating it. If we are very cold we start to shiver. Shivering is an automatic movement of the muscles which warms us and also tells us that we must do some exercise to keep warm or move to a warmer place.

HUMIDITY AND THE BODY

The quicker the perspiration evaporates on our skin, the more we are cooled. If there is no evaporation we are not cooled at all. Perspiration is mostly water and whether it evaporates or not depends on the amount of water vapour in the air around us. When the relative humidity is high the perspiration can only evaporate slowly. When the relative humidity is low it can evaporate quickly. We find it much easier to keep cool when the air is dry than when it is damp.

KEEPING WARM

In Britain we have to think more often about keeping warm than about keeping cool. Our bodies, like any other objects, can gain or lose heat in three ways: by direct contact with something warmer or cooler, by the flow of warm or cool air past them, and by the exchange of heat rays with objects round them. These three ways in which heat travels from one place to another are called conduction, convection and radiation respectively.

Conduction

If the point of a poker is placed in a fire, the handle

very soon becomes warm and, after a while, may become too hot to hold. Apart from the tip getting red-hot there is no change in the poker that we can see, yet heat has travelled along it and made the temperature of the handle too high to touch. We say that heat has been conducted along the poker.

You learned in Chapter 1 that it is the vibrations of molecules which we feel as heat. If one end of a bar of metal is heated, the molecules at that end vibrate more violently than the rest. These jostle the molecules next to them and cause them to vibrate more violently, and so on all along the metal. If we touch any spot on the metal we can feel it getting warmer. We can feel the heat being conducted along the metal.

Good conductors	*Bad conductors*
Silver	Water
Copper	Glycerine
Aluminium	Paraffin
Zinc	Glass
Iron	Cement
Lead	Wood
Mercury	Asbestos
	Bricks
	Fabrics
	Gases

In each column the best conductors in the group are at the top and the worst at the bottom.

A very bad conductor of heat is called a heat insulator.

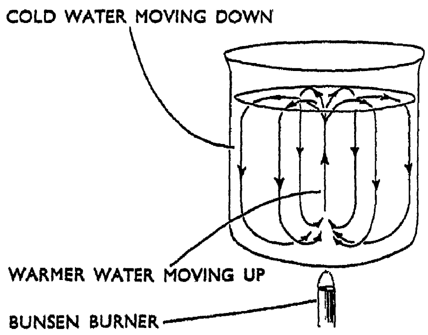
Some materials are better conductors of heat than others. Solids are generally better than liquids and both are much better than gases. This is because the molecules in solids are so tightly packed that it is impossible for one

to change its vibration without affecting the others round it. The molecules in liquids are less tightly packed and it is possible for some of them to vibrate more without affecting the molecules round them very much. In gases the molecules are so far apart that they have practically no effect on each other whatever they do.

Convection

In Book Two you learned that the winds of the Earth are caused by the unequal heating of different parts of the atmosphere and that the flow of water in a hot-water system is caused by heating a part of the water. Both of these are cases of convection. Convection takes place in liquids and gases but cannot take place in a solid.

When a beaker is heated over a small gas flame, heat is conducted through the glass to the water. The water in contact with the heated glass gets hot and expands. It therefore becomes lighter and is pushed out of the way



by the cold, denser water round it. This cold water is heated, becomes less dense and, in turn, is pushed up by more cold water. This starts a circulation in which the colder water in the beaker is always pushing down to the hot part of the beaker and causing the warmed water to

rise. Each molecule of the water goes round and round with the circulation, picking up a small amount of heat each time it touches the hot part of the beaker. The temperature of the water gradually rises.

Anything which causes one part of a liquid or a gas to be warmed will start a convection current. When you are standing in air which is cooler than your body, the air in direct contact with you is heated and starts a convection current above you rather like the smoke from a chimney.

Radiation

On a sunny summer day we can feel the heat which comes from the sun. If a cloud gets in the way, the heat is stopped at the same time as the direct light from the sun is cut off. Heat from the sun travels to us through space along the same straight lines that light travels. This sort of heat is called radiant heat. It is the same kind of radiation as light but it affects the skin instead of the eyes. Most solids and liquids will stop it, but it passes through air and gases without much hindrance.

Radiant heat is reflected in the same way as light. Shiny surfaces and pale coloured surfaces which reflect a lot of light, also reflect much of the radiant heat falling on them. Dark coloured surfaces which absorb most of the light falling on them, also absorb radiant heat and become warmed by it. An object which is painted white will keep cooler in the sunshine than a similar object which is painted black. Only objects which stop and absorb radiant heat can be warmed by it.

All things are giving out radiant heat all the time. If they are absorbing more radiant heat from their surroundings than they are giving out, they get warmer. If they absorb less than they are giving out, they get cooler.

A good absorber of radiant heat is also a good radiator of heat, so dark things radiate heat better than light coloured or shiny ones. A black stove radiates more heat into a room than a similar stove which is white. A chromium-plated kettle would radiate less heat than a similar black kettle and so would keep the water hot longer.

CLOTHING

We wear clothes to prevent the loss of heat from our bodies. Clothing materials are heat insulators, and so we can stand on a cold pavement or sit on a cold seat without great discomfort. Clothing also traps a layer of still air round the body and prevents convection currents from cooling us too rapidly. Thirdly, clothing stops our bodies from radiating heat rapidly enough to make us cold.

The clothing we wear is enough to keep us warm at most times providing we are active, but, for a large part of the year in Britain, if we are sitting reading or doing work which does not call for much action, we need extra heat to keep us warm. We have fires in our homes, and central heating in our schools, offices and factories.

CONDITIONS OF COMFORT

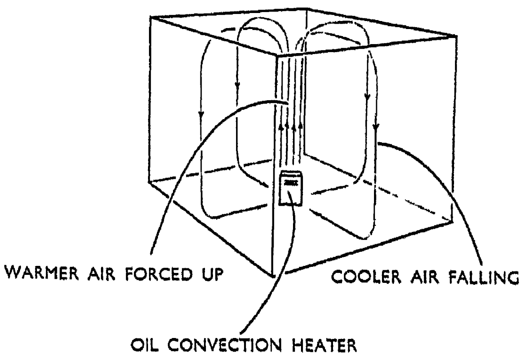
We feel comfortable when the body is losing just the amount of heat it is producing, without having to waste energy adjusting itself to its surroundings. This means that the air and things around must be at just the right temperature. We all differ in our ideas of what is comfortable, but, for most people sitting or doing light work in normal clothes, a temperature of 65° F. for the air and the surroundings appears to be satisfactory. We can also obtain comfortable conditions when it is cold either (*a*) by leaving the surroundings cold and heating the air.

as we do when we put an oil heater in a cold room, or (*b*) by leaving the air cold and making the surroundings radiate more heat. We do this when we make an electric reflector fire a part of our surroundings.

METHODS OF HEATING ROOMS

Rooms are heated mainly by convection and radiation. A heater which depends mainly on convection for its heating effect is called a convector, and one depending mainly on radiation is a radiator. All three ways of transferring heat occur to some extent in all heaters.

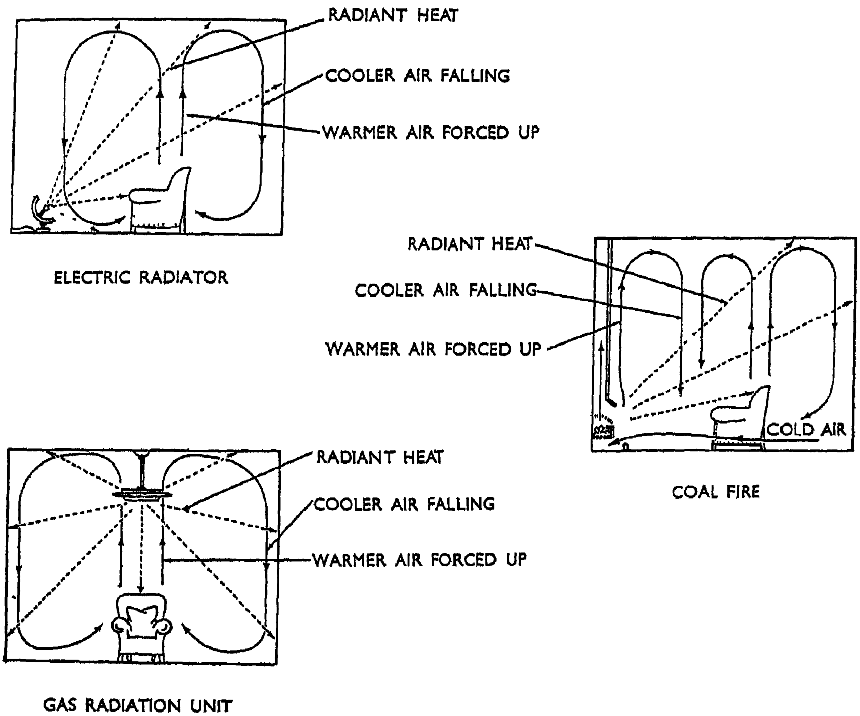
Among the convectors are oil heaters, hot water pipes, steam pipes, and gas and electrical convection heaters. The diagram shows an oil heater, in the middle of a room, heating the air by convection. The picture is very similar to that of water being heated by convection in a beaker. The same picture would hold for any convector, but the positions of the convection currents would change if the heater were in any other position in the room.



Oil convection heater

Among the radiators are the electric reflector fire, the coal fire, gas fires and electric and gas radiation units

which are suspended from the ceiling rather like lights. Radiators heat the furniture, floor and walls of a room, and these in turn heat the air by convection.



Radiation heaters

All types of heater cause the air to become drier because the relative humidity of the air becomes smaller as the temperature rises. An 18° F. rise in temperature of the air is sufficient to make the relative humidity fall to about half its original value. Gas appliances produce water vapour when they are burning and make up, to some

extent, for the drying of the air due to its rise in temperature.

AIR CONDITIONING

In some large buildings, instead of heating each room and passage separately, the air for the whole building is heated in one place. Air is drawn from outside by large fans, is cleaned, heated and given the correct humidity, and is then blown through ducts to various parts of the building. Other fans blow used air outside again. There is a continuous flow through the building, of pure air at a comfortable temperature and humidity. Treating the air for a building in this way is called air conditioning.

NOISE AND COMFORT

Noise can be described as unwanted sound.

We very soon get used to regular sounds and completely ignore them. We get so used to the sound of a clock ticking that we do not hear it, although, strangely enough, we are immediately aware when it stops ticking. We soon get used to everyday sounds like traffic in the street or trains running nearby, and some people become so used to a radio set working continuously that they seldom really hear it, and yet they feel that something is missing when it is not working.

Any unexpected noise, even though it is not loud, distracts our attention and, if such noises happen frequently when we are trying to work, they can cause great discomfort and fatigue.

Regular noises, as long as they are not too loud, and noises which we have learned to expect, do not cause us discomfort.

TEN QUESTIONS FOR YOU TO ANSWER

1. What are the three main things which affect the comfort of the human body?

2. What is the internal temperature of a healthy human body?

3. Make a list of the things which happen to keep the body cool when you are playing energetic games.

4. Make a list of the things which happen to keep your body warm when you go into a cold room.

5. (*a*) What is the name of the method by which heat travels along a solid?

(*b*) What is the main method of heat transference in liquids and gases?

(*c*) What sort of heat is it that travels to us from the sun?

6. What are the two important forms of heat transference by which rooms are heated?

7. Draw a diagram to show how a room is heated by a coal fire.

8. Explain how clothing keeps you warm.

9. What do we mean when we say that a building is air-conditioned?

10. Write down (*a*) two examples of sounds which do not worry you when you are working, and

(*b*) two examples of sounds which do annoy you.

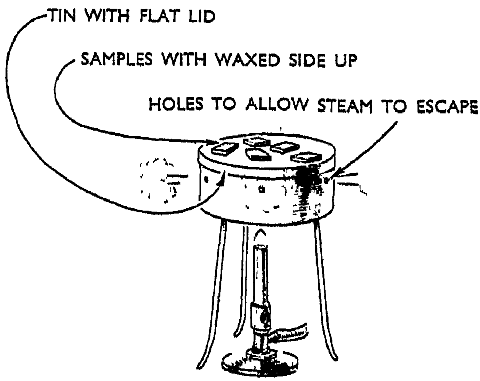
THINGS TO BE DONE

1. Find out what a clinical thermometer is like and how it works (Book I). Draw a labelled diagram in your book. Find out how the thermometer is used and, if you can obtain one, take the temperature of your own body.

2. Find out what the body temperature is in degrees centigrade and also what a temperature of 65° F. is in degrees centigrade.

3. Next time you run a long distance or play an energetic game notice carefully all the things your body is doing to keep cool.

4. Obtain some pieces of different sheet metals about ½ in. to 1 in. square and all the same thickness. Obtain similar pieces of cardboard, different woods and plastics. It is important that the thickness should be the same in all cases. Paint one surface of each with paraffin wax which has been melted and has had blue powder paint mixed in to colour it. Obtain a tin with a large flat lid and knock or drill holes in the top of the sides. Half fill the tin with water and bring it to the boil. Steam will escape through the holes.



Place the metal samples, waxed surface up, on the hot lid of the tin and note how long it is before the wax melts on each Which conducts heat best? Which is the worst conductor?

Now try the other samples. Are metals better or worse conductors than the other materials?

Place a metal sample and the cardboard sample on the lid and leave until the wax on both has melted. Now move them quickly and place them on a cold surface. (The base of a retort stand will do.) Which cools quickest? Explain why.

5. Pour hot water dyed with red ink very carefully and slowly

down the side of a beaker containing cold water dyed with blue ink. The hot water forms a separate layer above the cold water. Place a thermometer, without disturbing the water too much, so that its bulb is in the cold water. (There must be enough cold water to cover the bulb and about an inch of the stem of the thermometer.)

Watch the temperature of the thermometer. Is heat conducted down from the hot to the cold water? Is water a good conductor of heat?

6. When next you switch on an electric reflector fire, stand in front of it and watch the element. Describe what you see and feel in the first minute after switching on. Place a piece of paper or card between your face and the fire. Can you still feel the heat? Now move round the fire and note when you can, and when you cannot, feel the heat from it. In what ways are radiant heat and light similar?

7. Obtain two similar syrup tins and knock a hole in the middle of each lid. In each hole place a thermometer, and fix it in position with plasticine. The thermometers should be alike and the bulbs should be about 1½ in. inside the tins. Paint one tin white and one tin black, let them dry, then tie string round each and hang them from some support close together in sunshine and a few feet from the ground. Watch the temperatures of the two thermometers and explain what happens. Now fill the tins with water from the tap, making quite sure you have the same amount of water in each. Read the temperature of the water every ten minutes and make a table and graph of your results. If you can obtain more tins of the same kind try painting each a different colour. Repeat the experiment and try to discover which colours absorb most radiant heat from the sun.

8. Find examples of different methods of heating rooms used in your own home, in the homes of your friends and in your school. Describe the methods and draw diagrams to illustrate them.

9. Explain why a dirty patch often forms on the wall above a hot-water radiator.

CHAPTER 8

Seeing

LIGHT AND COMFORT

WHEN A BRIGHT LIGHT shines in your eyes, or when you look in the direction of something which is very much brighter than its surroundings, you feel uncomfortable. Your eyes feel tired and you may get a headache. You may also become tired if you have to look at an object on which too little light is falling. The best light for the eyes is that found out-of-doors on a day when thin clouds cover the sky. The amount of daylight falling on an object on such a day may be one thousand times as great as the amount of artificial light falling on the same object indoors at night.

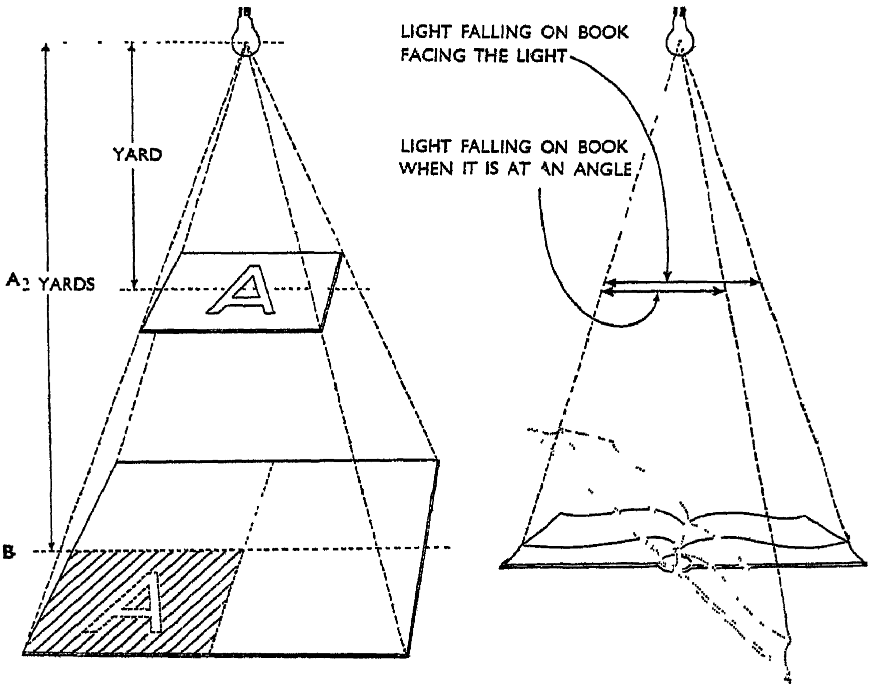
When you look at small things such as very fine print, or small stitches, you tire more quickly than when you are looking at large objects. You also tire more quickly when you are looking at moving things, or things in which there is not much colour contrast. In any of these cases an improvement can be made by increasing the amount of light falling on the things at which you are looking.

ILLUMINATION

When light falls on an object, for example on the page of this book, we say that the object is illuminated. Illumination is a measure of the amount of light falling on one square foot of an object. Two similar lamps placed side by side will give twice the illumination given by one, three lamps will give three times as much illumination as one,

and so on. The illumination on a surface is proportional to the strength of the source of the light.

The distance of the surface from the source is also important. If you are reading one yard from an electric light and then move to a chair two yards from the light, only one quarter as much light will fall on the book. If you



Illumination at B is $\frac{1}{4}$ × illumination at A

move three yards from the light only one ninth of the original light will fall on the book. The further you move from the light the weaker will be the illumination on the book. How you hold your book is also important. When the page is directly facing the light, more light falls on it

than when it is held at an angle, and so the illumination is better.

Glare is the name given to light which dazzles us or makes us feel uncomfortable. Glare may come from light sources, from reflections in polished surfaces, or from objects which are very much brighter than their surroundings. We can prevent the discomfort by moving ourselves, or the source of the glare, so that the light from it does not enter the eye directly. When we are out of doors on a sunny day we cannot always look away from the sun, so we wear dark glasses to prevent glare. Watching a bright television screen in a dark room causes discomfort because of glare. To watch television without discomfort you should have some light in the rest of the room, particularly on objects round the set.

LIGHTING A ROOM AT NIGHT

The main light in a room is usually in the middle of the ceiling. If you are working at a table immediately beneath it your work may be well illuminated. If you move the table to the side of the room, the light will be much poorer because you are farther from the lamp and because the rays of light are falling at an angle on your work. The new illumination may be only one fifth of the original. The ceiling and the walls, especially if they are light in colour, will reflect some useful light, but the amount depends on the kind of lamp-shade or bowl used. Some bowls send most of their light up to the ceiling which reflects the light and spreads it evenly through the room. This spread or diffused light is not good enough for long periods of reading or fine work, and so "local" lights, such as reading lamps and standard lamps, are used to give light just where it is wanted. As the local lights are usually near

to the illuminated surface they do not have to be of great power. A single lamp one foot away from a surface will give the same illumination as four similar lamps two feet away, or nine similar lamps three feet away.

AIDS TO SEEING

In clear weather we can easily see a ship ten miles out to sea, and from a high cliff we can see further still. At night we can see stars which are millions of miles away. Even the nearest star is at such a great distance from the Earth that light, which travels at 186,000 miles per second, takes four years to reach us.

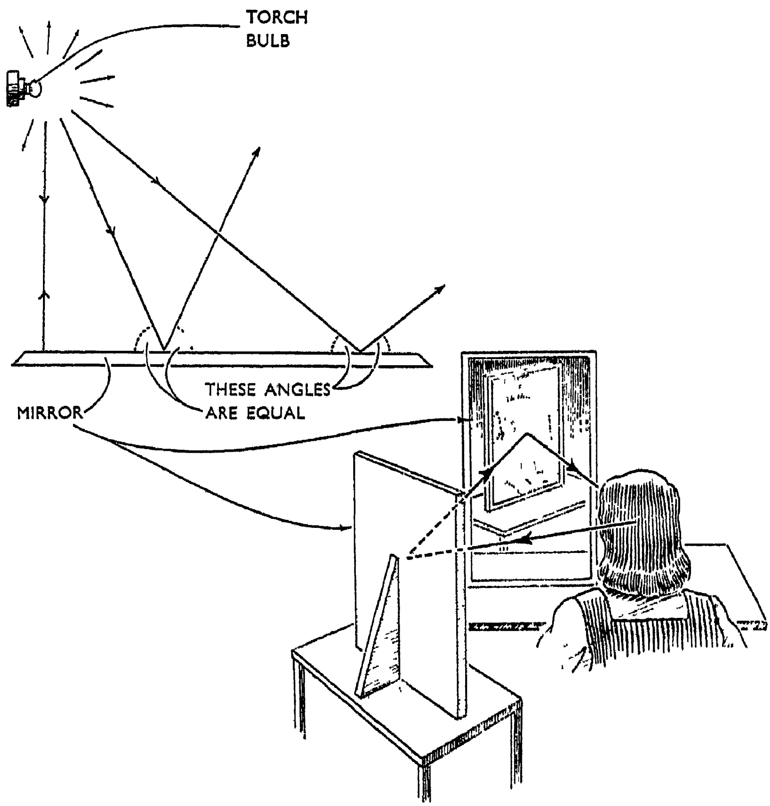
There are many things which are too small for us to see clearly even if we illuminate them brightly. Men have invented instruments to help us see things which are too small, or too far away, to be seen without aid. Most of the aids to seeing depend on the reflection of light by mirrors, and the effect on light of transparent materials such as glass.

MIRRORS AND REFLECTION

Rays of light which strike a mirror are reflected. They bounce back from the mirror in much the same way as a tennis ball bounces when it strikes a smooth surface. A tennis ball thrown straight down at the ground bounces back along the same line, but if it is thrown to hit the ground at an angle it bounces off at the same angle in the opposite direction. Light does the same when it hits a mirror. A mirror which is flat like a looking glass is called a plane mirror.

If you stand in front of a looking glass you see a reflection or image of yourself because light from you is hitting

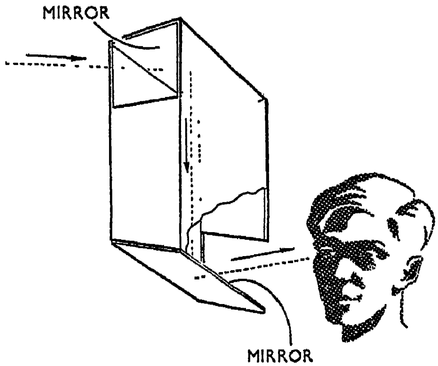
the mirror and being reflected back to your eyes. Your image is as far behind the mirror as you are in front, it is the same size as you, and it is reversed from left to right.



Mirror reflection

By using two mirrors you can see the back of your head. Try to think why the image you see is the right way round. You can make use of the side mirrors found on many dressing tables to make sure you are clean and tidy from all directions, and not just from the front view you usually

see in a mirror. In a periscope, two mirrors are used in a slightly different way. Periscopes are used to see over high



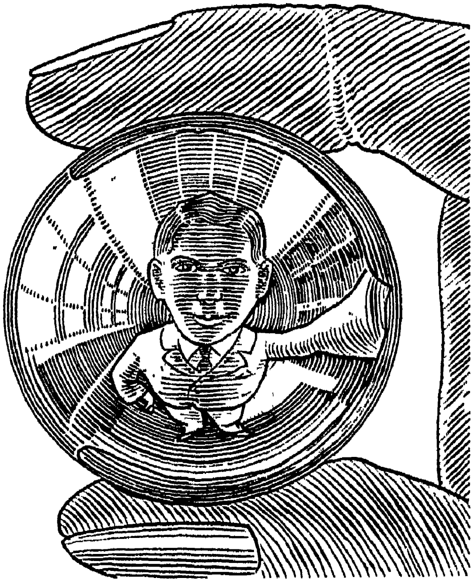
The periscope

obstacles, or to see a procession from the back of a crowd. Special periscopes are used in submarines so that the crew can see what is happening on the surface of the sea when they are submerged.

Curved Mirrors

A steel ball-bearing acts as a mirror, but its curved surface gives an image which is much smaller than the image given by a plane mirror. If you look at a large ball-bearing, or at a silver ball used for Christmas tree decoration, you will see a reflection of the whole of your body and much of your surroundings. The image is very distorted especially near the edges where everything is squashed up. The chromium-plated hub covers on motor car wheels give similar images, and so do the backs of polished spoons and many other common objects. Mirrors like this, in which the reflecting surface bulges outwards, are called convex mirrors. In a convex mirror the image is always the

right way up and smaller than the object. Convex mirrors are often used for car driving mirrors because they give a wider angle of view than plane mirrors.

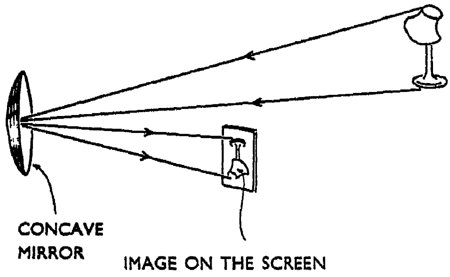


Reflection in a ball bearing

Concave Mirrors

When a mirror has a reflecting surface which is curved inwards like a very shallow cave, it is called a concave mirror. If you look into a concave mirror you will see that the reflections of objects some way from the mirror are all small and upside down, whereas the images of objects close to the mirror are the right way up and enlarged. If there is a bright object in front of the mirror an image of the object can be formed on a screen. When the object is a long way away, the distance between the mirror and the screen on which the image is formed is called the focal

length of the mirror. The inside surface of a polished spoon acts as a concave mirror. Concave mirrors are used in astronomer's telescopes. The largest in use at present is



The image formed by a concave mirror

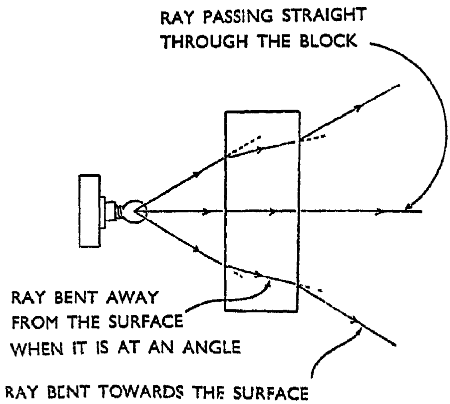
200 inches (16 feet 8 inches) across, and is at the Mount Palomar Observatory in California.

THE BENDING OF LIGHT

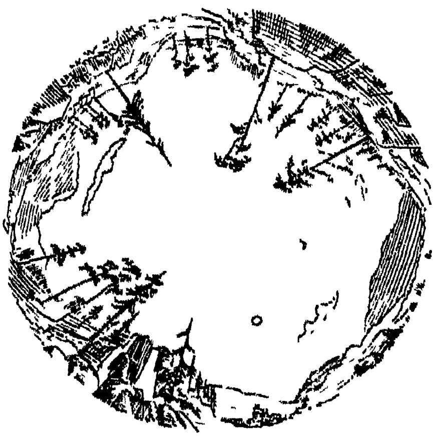
When you look into a swimming pool it looks much shallower than it really is. This is because the light rays from the bottom of the pool travel more quickly, and change their direction, when they leave the water and pass into the air. All the rays of light except those which hit the surface of the water at right-angles seem to be bent. Those which hit the surface at right-angles travel straight on, but at a faster speed. When light travels from a transparent material into air its path bends towards the surface of the material. If you try diving for a coin at the bottom of a swimming pool you will find that diving straight for the position where you see the coin will be a sure way of missing it. To pick it up you must dive between your own position and the place where the coin appears to be.

When light travels from air into a transparent material

its path seems to bend away from the surface of the material. If you can swim on your back under water in a



Rays of light passing through a block of glass



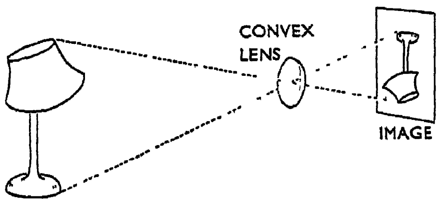
(*Left*) How a swimmer sees the world from underwater

(*Right*) What he would see if the surface were calm

swimming pool, you can see the whole scene of the pool in a circle above you. All round the circle the surface is green and you cannot see through it. You are getting a "fish's eye view" of the world above the water.

CONVEX LENSES

A block of glass with curved surfaces is called a lens. When the lens is thicker in the middle than at the edges, like a magnifying glass, it is called a convex lens. A convex lens will focus rays of light from a bright object to form an image on a screen. If the bright object is a long way away,



the distance between the lens and the screen on which the image is formed is called the focal length of the lens. When the lens is near the screen, the image formed is small and upside down. The lens of the eye and the lens in a camera work in this way. When the lens is near the object and the screen is a long way off a large image is formed which is upside down. If the lens is placed nearer than its focal length to the object no image can be obtained on a screen, but when you look through it you see an enlarged image the right way up. You are using the lens as a magnifying glass.

Microscopes. By using two convex lenses a greater magnification can be obtained than with one lens alone. The first lens forms an image which could be caught on a screen, and the second lens acts as an ordinary magnifying

glass to magnify the image formed by the first. The final image is upside down and reversed left to right but this does not matter in a microscope.

Telescopes. The same kind of arrangement is used in telescopes for studying the stars, and again it does not matter that the image is reversed. In telescopes and field glasses which are used to see things on the Earth it is necessary to obtain an image which is the right way up and the right way round. Either extra lenses or prisms are used to do this.

CONCAVE LENSES

Concave lenses are thinner in the middle than they are round the edges. They cause light passing through them to spread out or diverge. A concave lens will not form an image on a screen and when you look through one it always makes things look smaller.

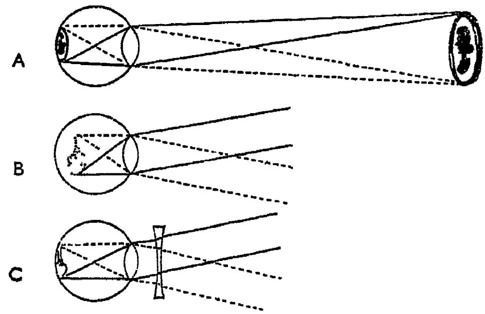
SPECTACLES

If our eyes are normal, when we look at an object we see it distinctly and in focus. This is because the thickness of the eye lens is adjusted automatically by small muscles to focus the object at which we are looking.

If you hold a pencil at arm's length and move it slowly towards your eyes, you will find that at first you can see it clearly, but when it gets nearer than about six inches it becomes blurred. A normal eye should, without effort, be able to adjust itself to see distinctly things which are nine inches away or more.

Many people possess eyes which, although they are otherwise quite healthy, have lenses which are unable to focus at all distances. Imperfect sight of this sort can be corrected by wearing spectacles.

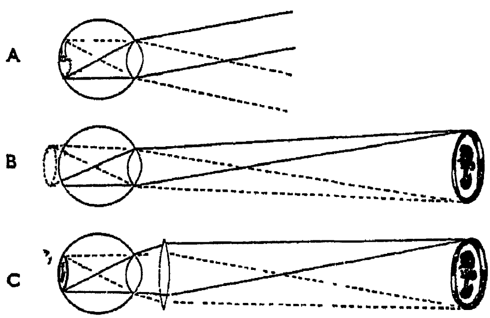
Short-sighted people can see close objects clearly but cannot focus on distant objects. This can be corrected with a concave lens. Long-sighted people can see clearly at a



Short sight

(a) Near object sharp focus (b) Distant object focused in front of retina (c) Concave lens brings the distant object into focus

distance but cannot focus on near objects. This can be corrected by means of a convex lens. The image of a distant object falls in front of the retina, as shown in the diagram. This can be corrected by placing in front of the



Long sight

(a) Distant object sharp focus (b) Near object would focus behind the retina (c) Convex lens brings the near object into focus

eye a concave lens which spreads the light and causes the image to form further back on the retina. Long-sighted people can see clearly at a distance but cannot focus on near objects. The image of the near object would fall behind the retina. This can be corrected by means of a convex lens, which converges the light and brings the image forward on to the retina. Most people become longer sighted as they grow older and eventually have to wear spectacles for reading and close work.

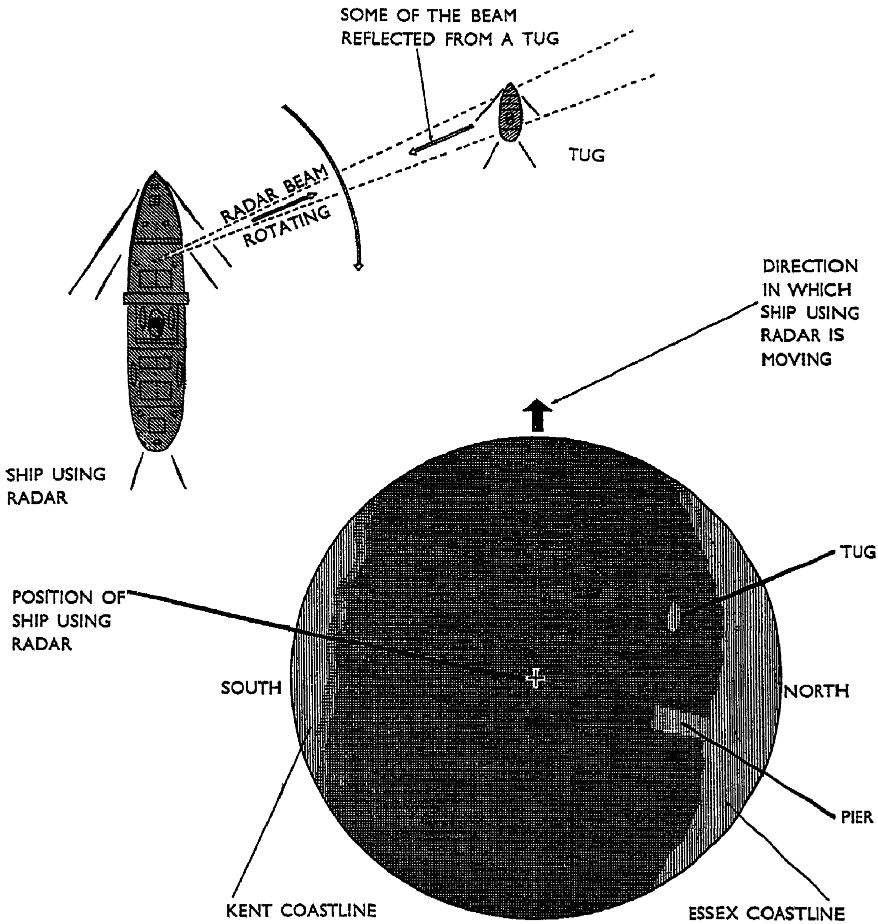
HOW RADIO HELPS US TO SEE

Radio waves are similar to light waves, but, unlike them, will pass through things like walls of houses and fogs. We make use of this fact in television and radar.

In the television studio the light from the scene in front of a special kind of camera is changed into a radio wave. This is broadcast from an aerial. We can think of a transmitting aerial as giving out radio waves in all directions in the same way as an electric light gives out light waves in all directions. In our television set the radio waves received by our aerial are turned back into a picture which is an image of the scene in the studio.

In radar a "searchlight" beam of very short waves is used. These short waves are reflected by solid objects in the same way as light, but they will pass through fog and clouds. The reflected waves are picked up on a special radio receiver and changed into a pattern on a screen similar to a television screen.

Radar can be used to find the position of an aircraft which is too far off to be seen, or which cannot be seen through fog or cloud. It is also used on ships to enable them to travel safely through fog. In ships a beam of radar waves is made to scan the water all round by means of a



rotating reflector. The beam swivels in the same way as the beam of light from a lighthouse rotates round the lighthouse. When the radar beam strikes another ship or the coastline, some of it is reflected. The reflected waves are picked up on a special receiving set and turned into a picture on a screen of the area round the ship.

TEN QUESTIONS TO ANSWER

1. What is a plane mirror?

2. Draw a diagram to show how a ray of light is reflected from a plane mirror.

3. Explain how a periscope works. Make a list of all the uses of plane mirrors that you know.

4. What is a convex mirror. What sort of image does it give?

5. What is a concave mirror?

6. Draw a diagram to show how the direction of a ray of light is changed when it enters a block of glass.

7. Make a list of the difference between convex and concave lenses.

8. What do we mean when we say that a person is short-sighted?

9. What sort of lens is used to correct long sight?

10. Describe two of the uses of radar.

THINGS TO DO

1. If your school has a ray apparatus, use it to show (*a*) how light is reflected from a flat mirror, and (*b*) how light is bent when it passes through a glass block and through a glass prism.

2. Obtain a torch, a sheet of white paper, a piece of thin card and a small plane mirror. Lay the white paper flat on the bench and set up the torch so that it shines across the paper from one side. Now cut a thin slit (width about 1 millimetre) across the card and arrange it upright between the torch and the paper so that a single line of light shines across the paper. You may have to move the torch farther away from the slit in order to obtain a sharp line of light. If the mirror is placed in the path of the line of light a reflected line will appear. Mark on the paper the position of the mirror and the two lines of light, then measure the angle between each line and the mirror. Repeat this experiment for several different positions of the mirror. What does this experiment show?

3. Obtain a block of glass with parallel sides and also a triangular glass prism and, using the apparatus set up in 2, experiment to see what happens when they are placed in turn in the path of the line of light. Try each in several positions.

Place the block of glass on edge on a line of print and look at the print through the width of the block. Does the print seem bigger or smaller than when the block is not there? Does the print seem nearer or farther away?

4. Obtain a concave and a convex mirror.

(*a*) Look into each in turn and describe what happens to your reflection as you bring the mirror from arm's length up close to your face.

(*b*) Use each mirror in turn and try to get an image of a window on a piece of white card. Which mirror will give a distinct image? Which way up is the image?

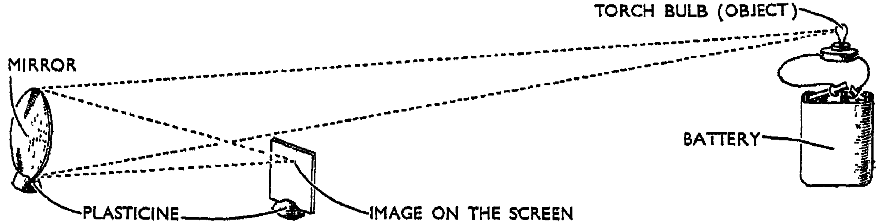
Use the mirror which gives a distinct image, to get an image on the screen of a tree or building a long way off outside the window. Measure the distance between the mirror and the screen. This is the focal length of the mirror.

(*c*) Obtain a torch bulb in a holder and connect it to a battery. Set it up a few yards away and use the mirror to obtain an image on the cardboard screen. If the room is too brightly lit you will have to shade the screen with a piece of cardboard.

Is the image larger or smaller than the torch bulb object? Which way up is it?

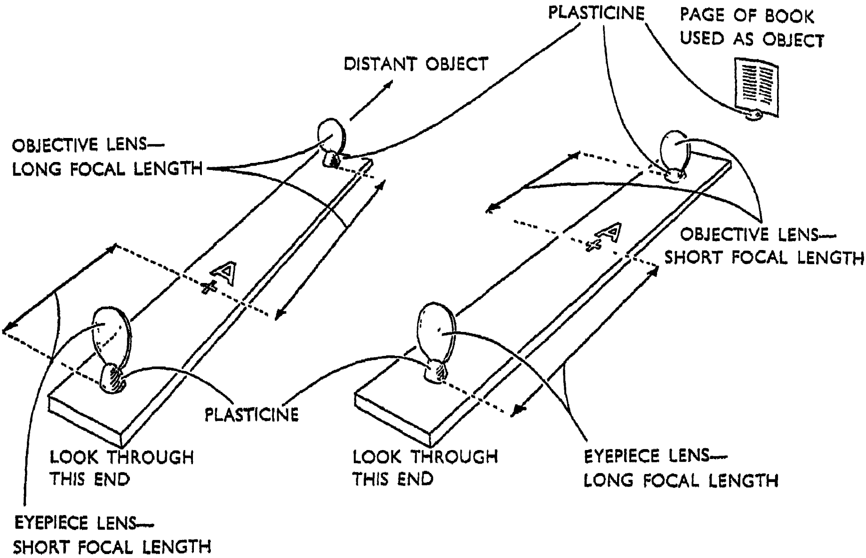
Now bring the light closer to the mirror and focus the image on the screen again. What happens to the image?

As you bring the light nearer and focus the image, note how the image changes. When the image is the same size as the object



measure the distance from the mirror. How does this distance compare with the focal length of the mirror?

When the light is so near the mirror that you can no longer obtain an image, look into the mirror and describe the image you see. If instead of the torch bulb you can use a car headlamp bulb connected to a low voltage electricity supply, or an electric light



Telescope Microscope

bulb connected to the main supply, the results are much easier to see.

5. (*a*) Obtain a concave and convex lens. Look through each in turn at a diagram in a book and describe the appearance of the image you see as the lens is moved from a few feet away from the diagram to right up close to it.

(*b*) Carry out experiments 4(*b*) and 4(*c*) but using lenses instead of mirrors.

6. Obtain one convex lens with a focal length of about 12 in. and one with a focal length of about 3 in. Find the focal length of each lens by the method used in 5 (*b*). Add the two focal lengths together then set the lenses up in line that distance apart, either in plasticine on a board or on a proper optical bench.

Try using different lenses of short focal length and see what effect they have on the magnification obtained when the apparatus is used as a microscope.

If you place a piece of ground glass or tracing paper at A the objective lens in each case forms a picture on it. If you look at the picture through the eyepiece lens you will see exactly the same image as when the screen is not there.

7. Find out how (*a*) a slide projector, OR (*b*) a photographic enlarger works. Draw diagrams and explain the uses of any lenses and mirrors used.

CHAPTER 9

Men, Work and Machines

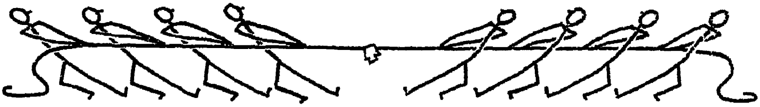
YOU HAVE LEARNED that men need heat to keep them warm, light to see and the movement of machines to help them in their work. You have also learned that they can get these from electricity, gas, coal and oil. Heat, light, movement and electricity are different kinds of energy. Coal, gas and oil are all stores of chemical energy. Energy is never lost, it just keeps changing from one kind to another. The chemical energy in gas, coal and oil is changed into heat and light energy when they burn; electricity changes into heat, and sometimes light as well, when it passes through a wire. Heat and light are easy to obtain from other forms of energy, but movement, which is the third form of energy men need, is not so easy to obtain.

FORCE

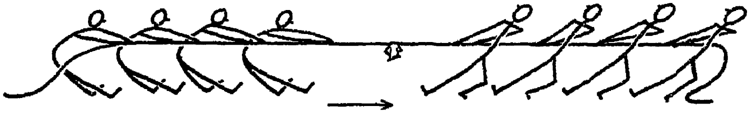
Things only move when they are forced to do so. When you bowl a ball along the ground you force it to move away from you. If you stop a ball which is travelling towards you, you force it to stop moving. Any change of movement, whether it is a speeding up or a slowing down, needs force. When you stop a ball, not only is your hand forcing the ball to stop, but at the same time the ball is forcing your hand back. You realize this if you try to stop a fast moving cricket ball or a netball.

We can describe force as a push or pull between two

objects. Each object exerts a force on the other. If the forces balance each other there is no movement.



Tug-of-war teams pulling equally, no movement

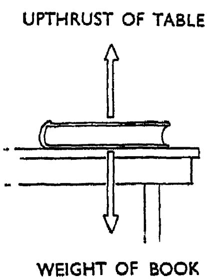


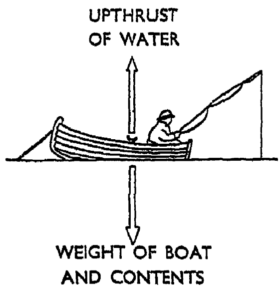
Tug-of-war teams with one team pulling harder than the other.

When one force is greater than the other, movement occurs. If one of the tug-of-war teams pulls harder there will be movement.

THE FORCE OF GRAVITY

If we are holding a ball and it slips out of our hand it falls to the ground. Wherever we are on the Earth the same thing will happen. The ball, and all other things on Earth, are always pulled towards the centre of the Earth

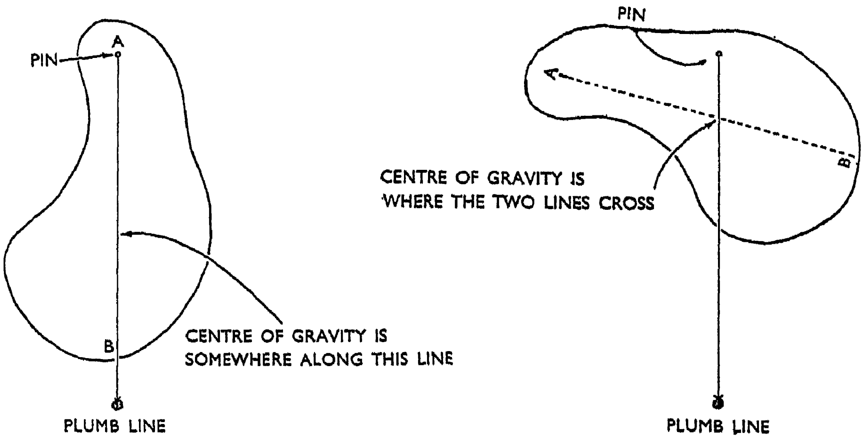




by a force called the Force of Gravity. The more massive the object, the greater is the pull on it. The strength of the Earth's pull on any object is called the weight of the

object. Weight is force and so any object will move downwards until it finds something to support it with an upward force equal to its weight.

The force of gravity acts on a body as though all the weight of the body were concentrated in one spot, called the centre of gravity. If we hang an odd-shaped piece of card by a pin near one edge, it will hang with its centre



of gravity directly beneath the pin. By trying this for several positions of the pin we can find the position of the centre of gravity.

WORK

When forces cause movement we say that they do work. The amount of work done depends on the size of the force and the distance it travels. Bigger forces and greater distances travelled mean more work. Work is measured by multiplying the size of the force by the distance it moves. The amount of work done in lifting a 3 lb. weight and putting it on a table 2 feet high is

$$
\begin{aligned}
&\text{force} \times \text{distance moved} \\
&= \text{weight} \times \text{the height of the table} \\
&= 3 \text{ lbs.} \times 2 \text{ feet} \\
&= 6 \text{ foot-pounds}
\end{aligned}
$$

Work is not done unless movement takes place. Tug-of-war teams can pull against each other until they are exhausted but no work is done unless one pulls harder than the other and they all start moving.

When you lift an object on to a table it does not matter how long you take, the work done is the same. A small engine can do any amount of work if it keeps going long enough.

POWER

This is the rate at which work is done—the amount of work done in each second. If the 3 lb. weight were lifted on to the table in 1 second, the power used would be 6 foot-pounds per second. The power of an engine is measured in horse-power. One horse-power is a rate of working of 550 foot-pounds per second. The greater the horse-power of an engine the more work it can do in any time.

ENGINES AND MACHINES

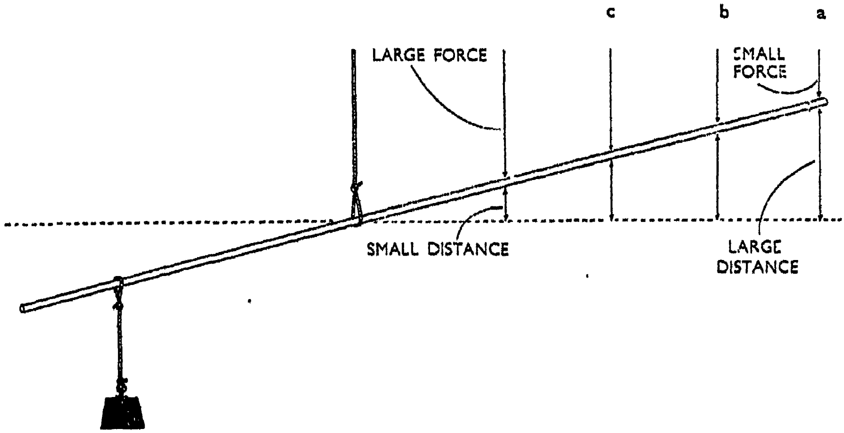
Engines are things which produce movement from some other form of energy. An electric motor is an engine because it turns electrical energy into moving energy. To get the movement from the engine to the place where we want work done, we use machines. When you ride a bicycle you are the engine which is causing the pedals to move. You do work on the pedals, but for the bicycle to move, the back wheel must do work. The cog wheels and

chain form a machine which passes on the work from the pedals to the back wheel.

Machines are not only complicated pieces of apparatus like sewing machines, printing machines, lathes and looms, but also simple things like knives and forks, stairs and hand tools. Without machines this world would be a very simple place. There would be no houses except caves and crude mud huts because there would be no saws, axes or knives. There would be no agriculture because there would be no forks, spades or hoes. In fact we should still be living as our very earliest ancestors must have lived.

LEVERS

Whenever you use a spanner to tighten a nut you are using a simple machine called a lever. The spanner



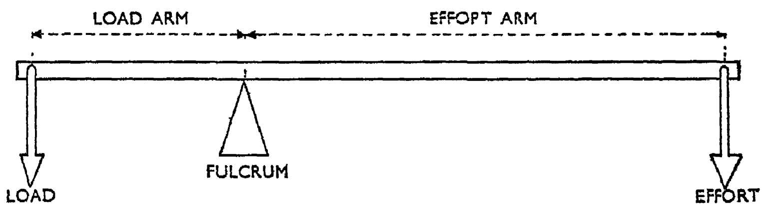
enables you to apply a much greater tightening force than you could with your fingers alone.

If you suspend a rod by a loop of string at its centre of gravity it will hang level, and if you push one end down,

the other end goes up. Suppose you tie a weight half-way along one side of the rod. The rod will be pulled to a vertical position. To lift the weight you must push down on the upper end of the rod. You apply a force which moves and you are doing work. The rod is being used as a lever to lift the weight. Now if you lower the lever so that the weight is supported on a bench or table top, you can try the effect of lifting the weight by pushing down at different points along the lever.

If you push down at the four points a, b, c and d in the diagram you find that as you get nearer the point of suspension you have to push harder. The force you have to exert gets bigger but the distance it works through to bring the rod level is smaller. The work done is the same in all cases.

When we are working with levers we call the resistance we are working against, the load, and the force which causes movement, the effort. The pivoting point of the lever is called the fulcrum. In the case above, the weight is the load and the force of the finger the effort. The effort gets smaller as its distance from the fulcrum gets bigger.

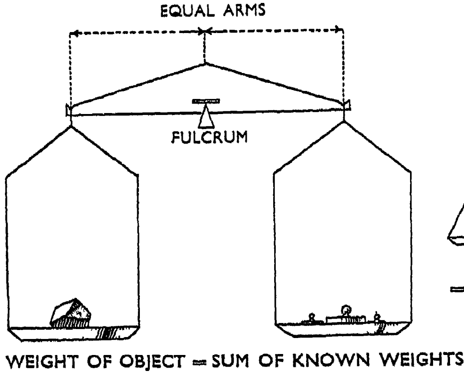


The law of levers is that

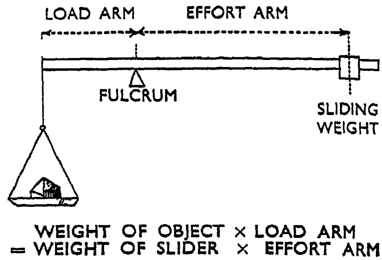
the load × length of load arm = effort × length of effort arm.

A lever can be used in three ways. The first way is with the fulcrum between the load and the effort. The chemical

balance and the steelyard balance are applications of this sort of lever.



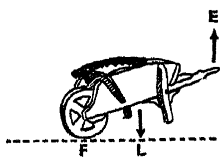
The chemical balance

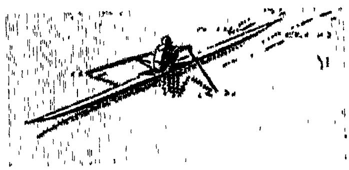


The steelyard balance

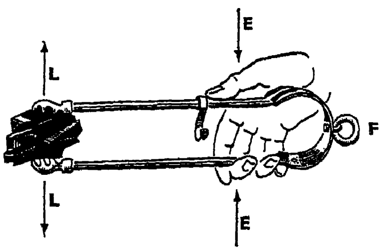
Many tools, like nippers, pliers and scissors, are double levers of this type.

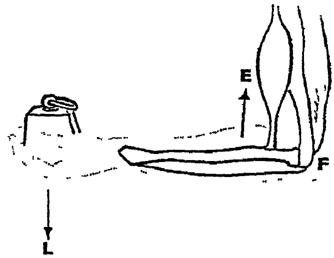
The second way of using a lever is with the fulcrum at one end, the effort at the other end and the load in between. No matter where the load is the effort is always a smaller force. Examples of this type of lever are the wheelbarrow and the rowing boat.





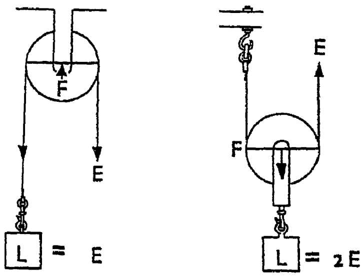
The third way of using a lever is with the fulcrum at one end, the load at the other end and the effort in the middle. Examples of the use of this type of lever are seen in coal tongs, sugar tongs and in the arm.





PULLEYS

A pulley is either a lever of the first type in which both arms are equal, or a lever of the second type in which the effort arm is twice the length of the load arm.

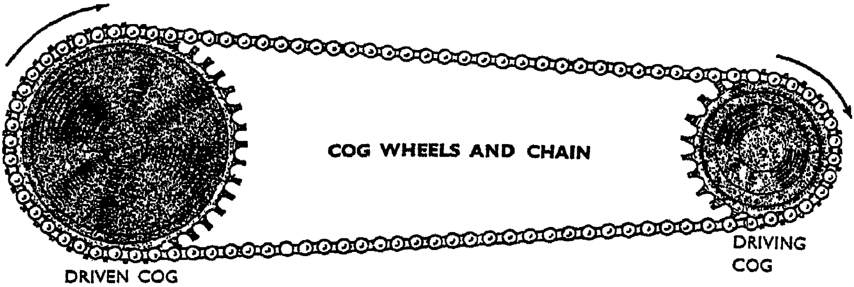


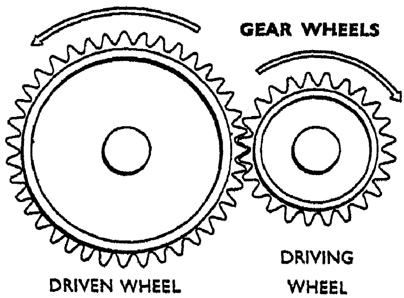
GEAR WHEELS

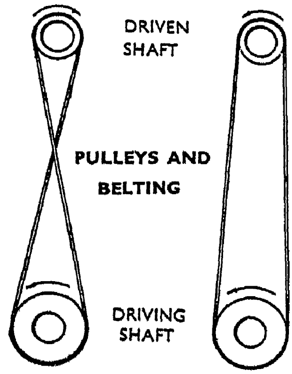
Gear wheels are applications of either first, second or third types of levers according to the position of the point driven by the previous stage of the machine, and the point driving the next stage.

Pulleys and gear wheels are often used more to get a particular speed of rotation in shafting than to transmit forces from one place to another. Pulleys can be a long

way apart linked by leather or fabric belting, cog wheels can be connected by means of a chain, and gear wheels work directly into one another.







Revolutions per minute of driven shaft =

$$\frac{\text{diameter of driving pulley}}{\text{diameter of driven pulley}} \times \text{revs per min. of driving shaft}$$

R.P.M. of driven cog =

$$\frac{\text{No. of teeth on driving cog}}{\text{No. of teeth on driven cog}} \times \text{R.P.M. of driving cog}$$

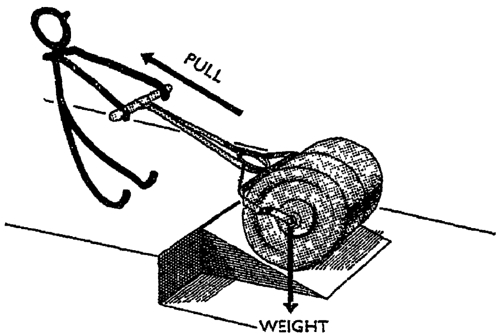
Gear wheels

R.P.M. of driven gear =

$$\frac{\text{No. of teeth on driving gear}}{\text{No. of teeth on driven gear}} \times \text{R.P.M. of driving gear}$$

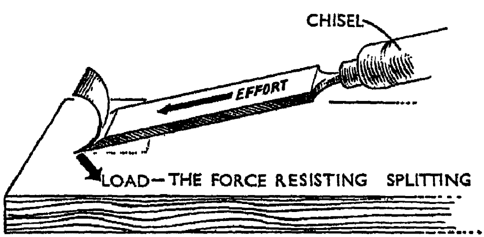
THE INCLINED PLANE

If you try to lift a garden roller up a step you find it extremely difficult if not impossible. If you use a ramp the roller can be pulled up it comparatively easily. The longer the slope the easier it is to get the roller on to the step. No matter how long the slope is, the work done is the same. It is the weight of the roller multiplied by the



height of the step. A ramp or slope is an inclined plane. It is a machine and enables small forces like the pull on the roller to overcome larger forces like the weight of the roller. In this case the load of the machine is the weight of the roller and the effort is the pull which moves it.

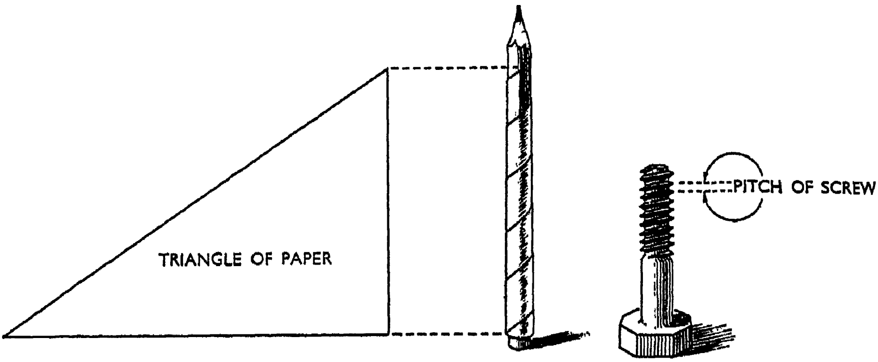
Wedges, wood chisels, cold chisels, needles, knives and similar tools are all examples of the use of the inclined plane.



The chisel as a simple machine

SCREWS

If you cut a triangular piece of paper to represent an inclined plane and wrap it round a pencil, you see that the sloping side of the triangle makes a spiral round the pencil. A screw thread is a similar spiral of raised metal round a metal core. A screw is simply an inclined plane wrapped round a cylinder.



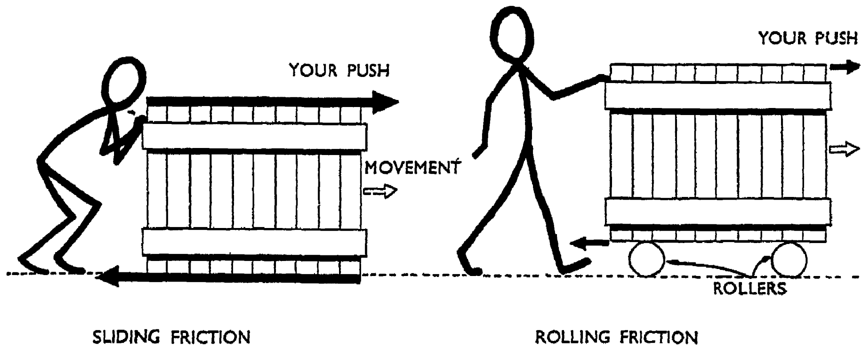
The distance between two turns in the thread of a screw is called the pitch of the screw. The finer the pitch of a screw the longer is the inclined plane to which it can be compared and the smaller the effort which is required to overcome a resistance.

RESISTANCE TO MOTION

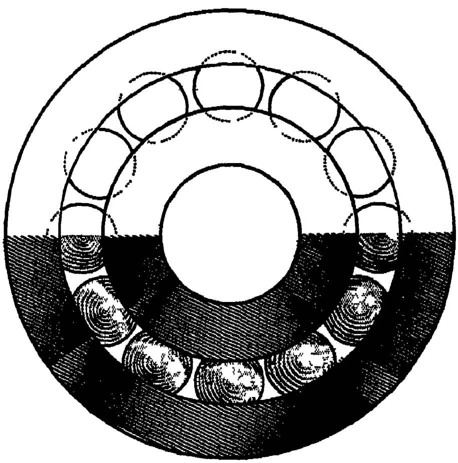
In all machines some energy is wasted, so that the work done by the machine is less than the work done on it. The wasted energy goes in overcoming friction and inertia, both of which resist motion.

Friction. If you try to push a heavy box across a level floor you find that you have to push very hard before you can make it start moving. When it is moving you have to

keep pushing to keep it moving. Even if the box is put on rollers you still have to exert a force although the task is much easier. The force which resists the movement of the box is called the force of friction.



The force of friction depends on the weight of the object being moved and the materials from which the



A ball bearing
The balls act as rollers between the spindle and the outer case

sliding surfaces are made. Rough surfaces give more friction than smooth ones.

When you try to slide one object over another you always find that it takes a bigger force to start movement than it does to keep it going. The friction you overcome in making an object move is called limiting friction, and the friction overcome in keeping it moving is called sliding friction.

Rolling friction is very much less than sliding friction because there is no actual sliding of either surface over the surface of the rollers. Wheels on vehicles and ball bearings in all types of machinery make use of rolling friction to lessen the wastage of energy which occurs when friction has to be overcome.

Inertia. When a heavy ball like a cricket ball or a netball is thrown at you hard you cannot stop it dead in mid-air. If you try you are likely to be hurt. You bring your hands back with the ball and gradually bring it to a stop. You are overcoming its inertia.

When you try to turn a grinding wheel or the fly-wheel of a sewing machine by hand you find that there is a resistance while the wheel is speeding up. Once it is moving it is easy to keep going. You have overcome the inertia of the wheel.

Inertia is the tendency of a moving body to keep moving or of a body which is still to remain still. Work is always required to overcome inertia. Inertia is a hindrance when a machine is being started, but the inertia of a fly-wheel is used to keep a machine in motion and to make it run smoothly.

Both friction and inertia waste energy. The best we can do is to design machines which make the wastage as small as possible. On the other hand both friction and inertia are essential to us. Without friction we should not

be able to stand or walk along. We should not be able to use nails or screws to hold things together. Without inertia a ball could not be thrown as it would drop to the ground as soon as it left our hand, and engines and machines would work in a very jerky way if they worked at all.

COMPLEX MACHINES

Pieces of machinery which contain several simple machines linked together are called complex machines. Most complex machines contain only levers and inclined planes and their applications. The more complex a machine is the more important the losses due to friction and inertia become.

The important thing we want to know about any machine is how the work done by the machine compares with the work we have to do on the machine. The measurement we make to determine this is called the efficiency of the machine.

$$\text{Efficiency} = \frac{\text{Work got out}}{\text{Work put in}} \times 100 \text{ per cent}$$

A machine which is 50 per cent efficient is one in which we only get out of the machine one half of the work we put into it, the other half being wasted mainly in overcoming friction.

For any machine the work done on the machine is the effort multiplied by the distance the effort moves, and the work done by the machine is the load multiplied by the distance moved by the load.

TEN QUESTIONS

1. Write down the names of as many forms of energy as you can think of.

2. How many foot-pounds weight of work would you do if you lifted a box weighing 20 pounds from the floor and put it on a shelf 5 feet above the floor?

3. What do we mean when we talk about the weight of an object?

4. What is meant by "power"?

5. A rod of wood 24 in. long is hung up by means of a loop of string round its middle point, and a 4 lb. weight is hung 3 in. away from the suspension. What weight hung from the far end of the rod would just balance the 4 lb. weight?

6. Draw diagrams of the three ways in which a lever can be used, showing the position of load, effort, and fulcrum in each case. Write down the names of three applications of each order of lever.

7. Explain how you can show simply that a screw thread is really only an inclined plane. Name two other applications of the inclined plane.

8. If a gear wheel with 40 teeth rotating once each second drives a gear wheel with only 10 teeth, how fast does the small gear wheel rotate?

9. What do we mean by the "efficiency" of a machine?

10. Make a list of the ways in which (*a*) friction and (*b*) inertia are useful to us.

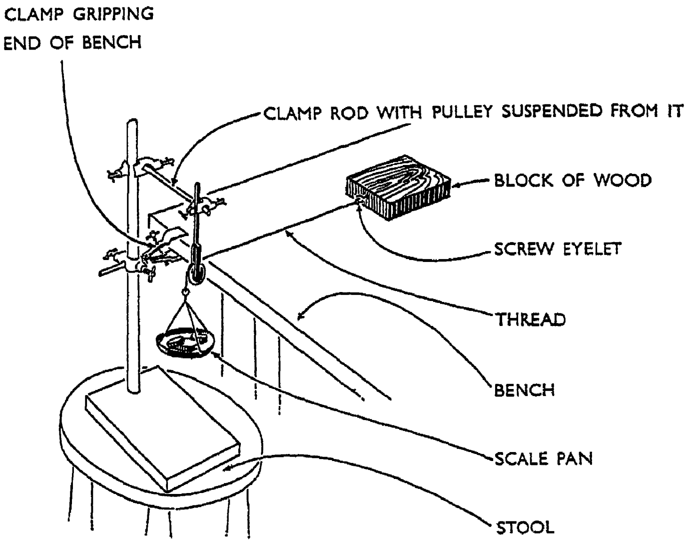
THINGS TO DO

1. Make a list of the natural sources of energy and power to be found on the Earth (for instance, coal and wind power), and write a few lines about each stating what it is used for.

2. Find out what you weigh in pounds and then work out a way of measuring the height in feet of the top floor of your home or school above ground level. Multiply your weight by the height found to give you the number of foot-pounds of work you

do in going up the staircase from bottom to top of the building. Whether you walk or run this amount of work will be the same.

Measure how many seconds you take to walk upstairs to the top of the building then work out how many foot-pounds of work you are doing in each second. Divide this number by 550 to find your horse-power.



Now time yourself running upstairs and work out your horse-power in this case.

3. Cut five shapes from cardboard, (1) a triangle, (2) a square, (3) a circle, (4) any odd shape and (5) a U-shape. Cut them so that they are at least 6 in. across their widest part. Find their centres of gravity by the method outlined in the chapter.

Could you find the centre of gravity of any of these shapes by a drawing method without carrying out the experiment? Is the centre of gravity of an object always inside the material from which the object is made?

4. If you have a friction apparatus at your school use it to carry out the following experiment, otherwise set up apparatus similar to that shown in the diagram above. Find out what weight in

the scale pan just causes the wooden block to slide. (Do not forget that the weight of the scale pan itself is helping to move the block.)

The weight you obtain is the force necessary to overcome the limiting friction between the block and the bench top. If you weigh the block and divide its weight into the force needed to cause it to move you obtain a coefficient of friction.

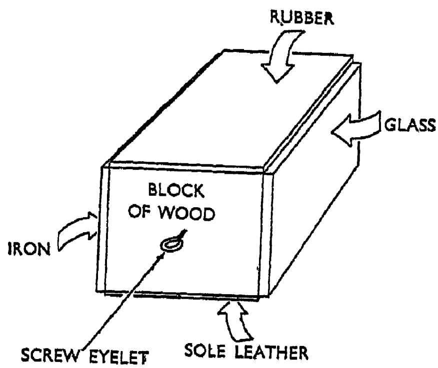
The coefficient of friction between two materials equals

$$\frac{\text{the force necessary to make one slide on the other}}{\text{the weight of the object which slides}}$$

It depends only on the materials of which the sliding surfaces are made.

Now place the wooden block on two wooden rollers (two pieces of dowel or two wooden penholders), and find what weight is needed to move it. Is it easier or more difficult to move?

Obtain a block of wood about 3 in. square and 4 in. long and



stick leather to one face, rubber to another, a sheet of glass to the third and a sheet of iron to the fourth. Rubber solution will stick even the glass and iron in position providing they are cleaned thoroughly first.

By causing each surface of the block in turn to slide on the bench top (wood), on a large sheet of glass, on a large sheet of

iron and on a piece of paving stone or concrete, obtain results to fill in the following table:

Weights needed to overcome limiting friction for different pairs of surfaces:

Material on the block / *Material placed on bench*	LEATHER	RUBBER	GLASS	IRON
WOOD				
GLASS				
IRON				
CONCRETE				

Find what effect oiling the metal surfaces has when they are in contact.

Find the effect of wetting the large sheets of glass, iron and concrete and making each of the block surfaces slide on them.

What do these experiments tell you about the oiling of machinery and about the materials (leather, rubber and iron) you may have on the bottoms of your shoes?

5. Examine a bicycle or sewing machine and find as many examples as you can of applications of simple levers and inclined planes. (Look for levers, pulleys, gears and cogs, cams, screws, etc.) Draw a diagram of each example in your book and explain its use.

6. Make up pulley and belting systems, cog and chain systems and gear wheel systems from Meccano or from laboratory apparatus. Test the formulae given in the chapter connecting the speed of rotation of the driving and driven wheels.

CHAPTER 10

Electricity

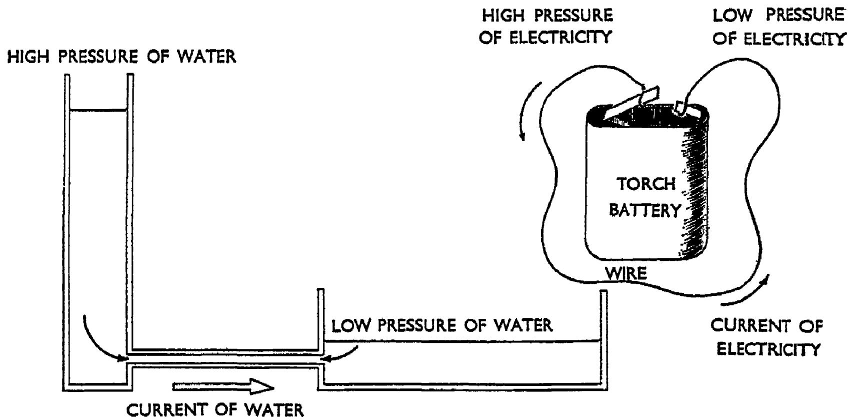
ELECTRICITY IS IMPORTANT because it is the easiest form of energy to transfer from one place to another. When it is where we want it we can turn it into heat energy and light energy which are essential to life, or we can use it to make machines do work for us.

The electricity may be produced by a generator which is turned by a motor using any of the other forms of energy. When we switch on a light we might be obtaining energy made from the chemical energy of coal, as it is in a London power station, from the energy of flowing water, or even from an atomic energy power station.

ELECTRIC CURRENT, VOLTAGE AND WATTAGE

We can think about the electricity flowing through wire in the same way as we think about water flowing through a pipe. Water flows through a pipe when the pressure of the water at one end of the pipe is greater than the pressure at the other. In the same way electricity only flows through a wire when the pressure of electricity at one end is greater than the pressure at the other. Differences in electrical pressure are called voltage because they are measured in units called volts. Electric currents are measured in units called amperes. If we were to try different sizes of tubing in the water flow apparatus shown in the diagram we should find that the water flowed at very different rates. Wide tubes would not offer much resistance to the flow and the current of water would be large. Narrow tubes would

resist the flow of water and the current would be small. The same sort of thing occurs in electricity. The thinner a wire is the more it resists the flow of electricity through it. On the other hand thick wires offer very little resistance and large currents flow. The greater the resistance the



bigger is the voltage needed to send a given current through the wire. We measure resistance by finding the number of volts which would be needed to send a current of 1 ampere through the wire. The resistance of any apparatus can be found by dividing the voltage applied to it by the current which flows.

$$\text{RESISTANCE} = \frac{\text{VOLTS}}{\text{AMPERES}}$$

Instead of calling the units volts per ampere we give them the special new name ohms. A car headlamp which passes 3 amperes when a pressure of 12 volts is applied to it would require 4 volts to make 1 ampere flow. Its resistance is equal to

$$\frac{12\ (\text{volts})}{3\ (\text{amps})} = 4 \text{ ohms.}$$

DIRECT CURRENT AND ALTERNATING CURRENT

When the electric current keeps flowing in the same direction as it does from a battery we call it Direct Current or D.C. In producing electricity on a large scale it is more convenient to make electricity in which the current flows backwards and forwards along the wires. Current which flows first one way then the other is called Alternating Current or A.C. In Britain we use A.C. which changes its flow from one direction to the other and back again fifty times each second. We say the supply has a frequency of 50 cycles/second. Heaters and light bulbs can be used on either D.C. or A.C. providing they are the right voltage, but other electrical appliances will often work only on D.C. or on A.C. supplies. Each appliance should be marked with the voltage, wattage and type of supply it is designed to work on.

WATTAGE

The rate at which electrical energy is used is measured in units called watts. The watt is a unit of power. To find the wattage of an appliance (the rate at which it uses energy) multiply the voltage by the current in amperes used by the appliance.

$$\text{Watts} = \text{volts} \times \text{amps}.$$

If, as is usually the case, we know the voltage and wattage of an appliance, we can find the current which it will take by dividing watts by volts.

$$\text{Amps} = \frac{\text{Watts}}{\text{volts}}$$

A 1000 watt fire connected to a 250 volt main would pass

a current of $\frac{1000}{250} = 4$ amperes. A 100 watt bulb connected to a 250 volt mains would pass $\frac{100}{250} = \cdot 4$ amperes.

It is important to know the current used by appliances you connect to your electricity mains. Whenever A.C. or D.C. electricity passes through a wire, heat is produced. We make use of this effect in electric heaters, but it also occurs in the rest of the wiring of a system where it is not wanted. If we try to take more current from the wires than they were intended to supply they become overheated and the rubber on them becomes hard and brittle. This may in time lead to a dangerous short circuit which will cause a serious fire.

FUSES

To prevent the overheating of the wiring in a house, either by using too much apparatus or by using faulty apparatus, fuses are connected into the various circuits.

Fuses are pieces of bare wire which melt when more than a certain current is passed through them. Each power point in a house should be connected to the main supply through a pair of fuses. The power point is marked with the current it is intended to supply and this is the rating of the fuse wire which should be connected in the circuit. A 15 ampere outlet should be protected by a 15 ampere fuse wire.

We can work out the wattage of apparatus we can safely connect to a 15 ampere outlet by multiplying the voltage of the supply by 15. (Watts = volts $\times$ amps.) If the voltage of our supply is 250 the total wattage of apparatus we could connect safely would be $250 \times 15 = 3750$ watts. A 2000 watt electric fire and a 2000 watt electric kettle connected to such a point would overload it. With a small overload like this the fuse in the circuit might not melt, but with continuous use the wiring connecting the point to the

fuses would become faulty. If our voltage were only 200, the total wattage of the apparatus we could connect safely would be only $200 \times 15 = 3000$ watts.

Three-way adaptors which connect into electricity points can be dangerous. You should always make sure that you are not connecting too great a wattage to a single point. Electric lighting is usually connected so that there are several light points to one pair of fuses rated at 5 amperes. If you are on a 250 volt main you can connect safely a total of $5 \times 250 = 1250$ watts to the lighting points. This would mean that you could have 12 100 watt lamps alight quite safely. If you were to connect a 1000 watt electric fire to one point there would only be 250 watts left for lighting the room and any other rooms on the same circuit. This may be enough for lighting purposes, but if somebody else decides to connect a fire to the light point in another room on the same circuit, the total wattage being taken from the fuse would be more than 2000, and it would melt.

When this happens some people put a heavier current fuse wire in the circuit and think they have cured the trouble because everything works. In fact they are storing trouble for themselves because wiring in the walls and under floorboards is being overheated, and may eventually cause serious damage which will cost a lot of money to put right.

RING MAINS

Many new houses are wired in such a way that several power points are connected to one pair of large main fuses. A cable from the fuses is connected to each power point in turn and then connected back into the fuses. There is a ring of cable with power points at intervals along it. With this type of circuit special plugs containing fuses are

connected to each piece of apparatus used on the supply. A fault in the apparatus causes its own fuse to blow and the rest of the system is not affected.

HOW ELECTRICITY IS MADE

Electricity can be produced in three ways:—

(*a*) by rubbing two materials together
(*b*) from chemical energy in cells, and
(*c*) from moving magnets.

FRICTIONAL OR STATIC ELECTRICITY

If you rub a fountain pen or ball-point pen on your sleeve, it becomes charged with electricity and you can pick up small pieces of paper with it. The sleeve has also been charged and small pieces of paper will stick to the part which has been rubbed. If you obtain two pens you can charge one and suspend it from a fine dry thread so that it hangs level. Then charge the other pen and bring it close to the first. The hanging pen will swing away. If you bring the part of your sleeve which was rubbed by the pens near to the hanging pen, it will be attracted. The charge on your sleeve is different from the charges on the pens. When two objects have the same sort of charge in them, they repel one another. When they have unlike charges, they attract each other.

When glass is rubbed with silk, we call the charge which comes on it a positive charge. The silk is negatively charged. How could you show that the charges on your fountain pens are negative?

CONDUCTORS AND INSULATORS

Materials like glass, plastics, silk and cloth hold charges for a long time because the electricity cannot move about easily in them.

If you try to charge a piece of metal by rubbing it on your coat you will get no result. Electricity flows easily in a metal, and the charge is lost through the metal and your hand as soon as it is formed. Materials like metals, through which electricity flows easily, are called conductors. Materials like glass and plastics, through which electricity flows only with great difficulty, are called insulators. Insulators are very bad conductors.

You can charge a piece of metal by rubbing it on your coat sleeve, providing you have an insulator between the piece of metal and your hand. You can wear a rubber glove or you can push the metal into a fountain pen cap and use that as a handle. See whether the charged metal repels a charged glass rod or a charged fountain pen. The charge on the metal will be the same as the charge it repels.

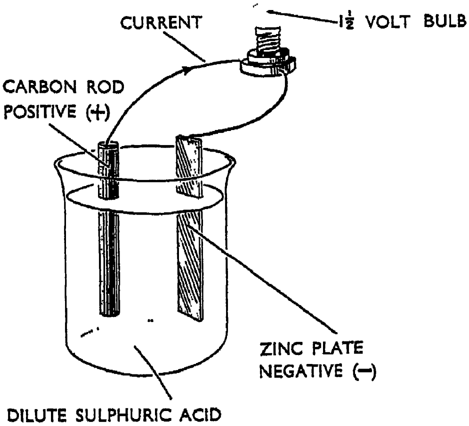
When two oppositely charged objects are brought close together, if the charges are large enough, a spark which can be seen and the crack of which can be heard, will pass from one to the other. The spark is caused by the electricity jumping the gap between the object which is negatively charged and the object which is positively charged. Both objects lose their charge. We say they become discharged.

Lightning is caused by very large electrical charges which build up in the clouds and which produce sparks across big gaps between different levels in the clouds or between the clouds and the ground. As the spark passes it produces a loud cracking sound and it is the echoes of this single sound that give the noise of thunder.

The amount of electricity which can be produced by rubbing is not sufficient for it to be of general practical use, but there are other ways in which we can get the amount we need.

ELECTRIC CELLS

The simplest way of obtaining useful small amounts of electricity is to obtain them directly from chemical energy. The device used to do this is called an electric cell. You can make a simple cell by placing the rod of carbon from an old torch battery and a piece of zinc in a beaker of dilute sulphuric acid. A chemical action takes place which causes

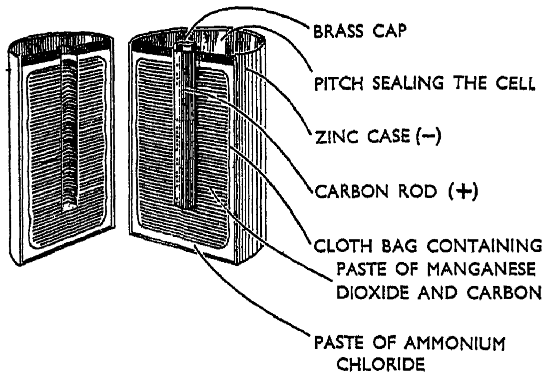


A simple cell

the carbon to become positively charged and the zinc to become negatively charged. When the carbon and zinc are connected by wire to a torch bulb, a current of electricity flows and makes the bulb light up. The current is said to flow from the positive to the negative side of the cell. The glow of the bulb soon dies down because of chemical

action which causes bubbles of hydrogen to form on the carbon rod. The hydrogen prevents electricity from flowing through the cell. A cell blocked by hydrogen is said to be polarized.

There are a number of cells which work in the same way as this simple one, but which have various means of slowing down the polarization which makes the cell useless. The only one we find in general use to-day is the dry cell, which is a modern version of an early liquid cell called the Leclanche cell.



A dry cell cut in half

DRY CELLS

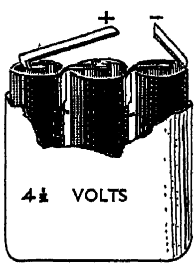
The diagram explains what you will see if you cut a dry cell from a torch battery in half with a metal saw and then separate the halves. In this the zinc plate of the simple cell has been shaped to form a container for the rest of the cell, and the sulphuric acid of the simple cell has been replaced by a paste containing ammonium chloride. Ammonium chloride is also called sal ammoniac. The manganese dioxide which occupies so much space is a

chemical which slows down the polarization in the cell. Notice that the contents of a usable cell are not dry. The name "dry cell" is not correct because if the cell were to become dry it would not work at all.

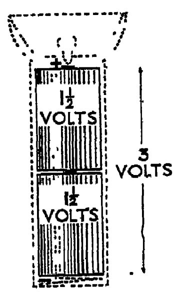
The electrical energy in any cell containing zinc comes from the chemical energy set free in the reaction between the liquid or paste and the zinc, which is gradually eaten away as the current flows. Dry cells stop giving electricity because they eventually do become polarized and not because the zinc has all been used up. It is possible to depolarize them by a method rather like charging an accumulator and then more of the energy of the zinc can be used. In this way the life of a cell can be made very much longer but the cost of the apparatus does not make it worth while for small batteries like torch batteries. Cells made from carbon, zinc and acid always have the same voltage. Each cell will supply $1\frac{1}{2}$ volts of electrical pressure.

BATTERIES

When two or more cells are connected together they make a battery. In most batteries of dry cells the cells are arranged with the positive centre terminal of each con



3 cells in series
$3 \times 1\frac{1}{2} = 4\frac{1}{2}$ volts

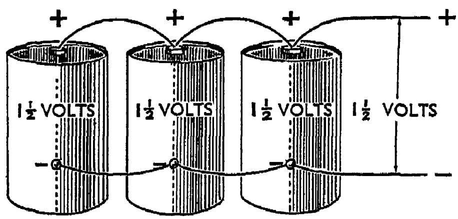


2 cells in series
$2 \times 1\frac{1}{2} = 3$ volts

nected to the negative zinc case of the next. When cells are connected like this they are said to be in series.

Radio high tension batteries are made by connecting large numbers of single dry cells in series. A 60 cell battery would have a voltage of $60 \times 1\frac{1}{2} = 90$ volts, and a 100 cell battery would give $100 \times 1\frac{1}{2} = 150$ volts.

When cells have the cases connected together and the positive caps connected together they are said to be in parallel. With such an arrangement the voltage is the same



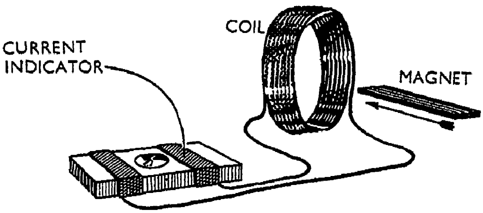
Three cells in parallel

as that of one cell but the current of electricity which can flow through connecting wires increases with the number of cells. You can either have a bigger flow of electricity than it is possible to get with one cell, or you can have the same current for a longer time.

MAGNETS AND ELECTRICITY

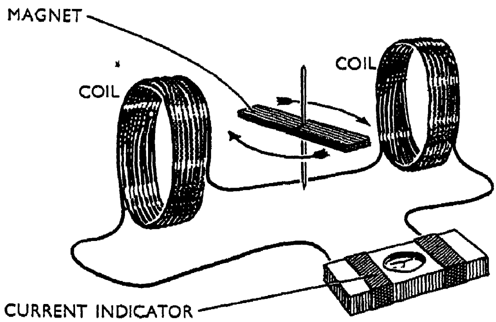
The most important method of making electricity nowadays is from the movement of a magnet of some kind. Whenever a magnet moves near a coil of wire it causes a current of electricity to flow in the wire. This can be shown easily if you have a coil of wire, a bar magnet, and a sensitive current meter, or the simple current indicator described in "Things To Do" No. 8. When the magnet moves into the coil the needle of the indicator flicks,

showing that a current is passing. When the magnet is still no current passes. When the magnet is drawn out of



the coil the needle of the indicator flicks in the opposite direction.

A simple generator of electricity consists of two coils of wire with a magnet turning between them. If the magnet



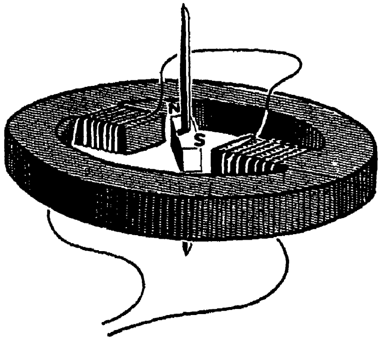
is rotated steadily the current indicator needle is deflected to the right then to the left in time with the movement of the magnet. The current flows first one way then the other. A.C. is being produced.

Most bicycle dynamos work on this simple principle but they are made more efficient by winding the coils round a core of soft iron. Cycle dynamos produce alternating current.

Even the biggest dynamos produce electricity in this simple way. They look very complicated because they

have large numbers of coils instead of two, and the magnet in the middle is an electromagnet worked by many more coils.

The natural form of electricity for a generator of this



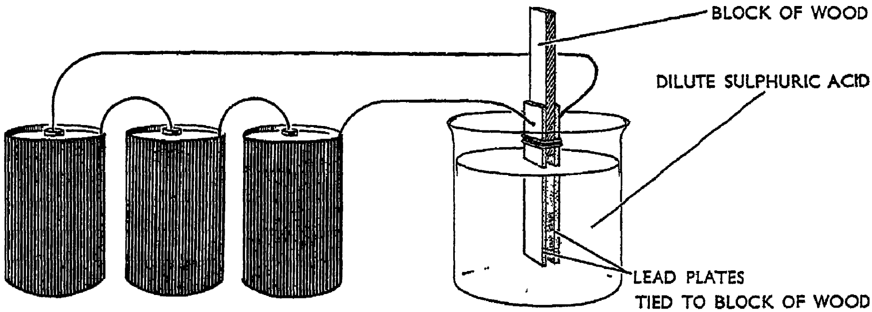
sort to produce is A.C. If D.C. is required the generator has to be complicated so that it sends electric currents out only in one direction.

STORING OF ELECTRICITY

Accumulators. An accumulator is a cell in which electricity can be stored. You can show the action of an accumulator by placing two strips of lead, about an inch wide, and a few inches long, in a beaker of dilute sulphuric acid. If you connect the plates with wires to a torch bulb it does not glow, and by using a voltmeter you can show that there is no voltage between them. When you connect the plates to a battery of three or more dry cells in series, bubbles are produced and the plate connected to the positive terminal turns brown. Electrical energy from the dry battery is being stored in the simple accumulator. After five or ten minutes if you disconnect the dry battery and try the lead plates once more with the torch bulb, you

find that it glows. The accumulator is giving out the electricity which has been stored in it. A voltmeter will show that there is an electrical pressure of more than 2 volts in the cell.

Accumulators in use to-day work on the same principle as this simple one, but they usually contain several pairs of plates connected in parallel, and the plates are grids containing a paste of red lead instead of being single sheets of lead. Such accumulators can give large continuous



Charging a simple accumulator

currents for quite long periods. When an accumulator becomes discharged it is recharged through a special charging apparatus from the electricity mains.

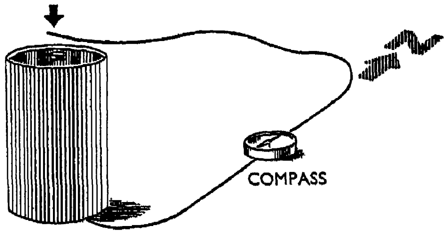
The relative density (also called the specific gravity) of the acid in an accumulator when it is fully charged is usually 1·25. The acid is $1\frac{1}{4}$ times as dense as water. As the cell discharges the relative density becomes less. It should never be allowed to drop below about 1·10 without recharging. Read the instructions on the label to see what figures the maker recommends for the particular accumulator you may use.

Batteries of accumulators may be made up in the same way as batteries of dry cells. Car batteries have either

three or six accumulator cells connected in series. As each cell gives 2 volts, car batteries are either 6 or 12 volt batteries.

USING ELECTRICITY

Electromagnets. In the last section you learned that a magnet moving near a coil of wire would cause a current of electricity in the wire. The opposite is also true. If a current of electricity is sent through a wire a nearby magnet may be made to move. This can be shown by placing a pocket compass over a wire which can be connected to a dry cell. Set the wire along the direction (the North-

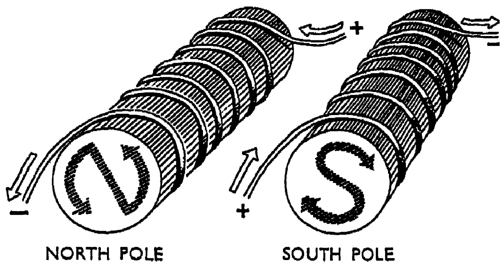


South direction) of the compass needle, and when you complete the circuit and a current flows, the needle will jerk round. Break the circuit and the needle returns to the North pointing position. This shows that the magnetic force causing the needle to turn was due to the current in the wire.

When a current of electricity is passed through a coil of wire the coil acts like a bar magnet. A coil can be made by winding about 50 turns of insulated copper wire on to a cardboard tube of about ½ inch diameter. A suitable wire is one of about 30 Standard Wire Gauge (S.W.G.), and a piece of an old thermometer case is suitable for the tube.

(The thickness of a wire is stated as a certain number S.W.G. or Standard Wire Gauge. The smaller the number the thicker the wire. Tables can be found in many electrical and radio books which tell you the actual diameter measurements in inches and centimetres of the various gauges. The tables will also often give other information such as the amount of current a certain size and type of wire will take.)

If the coil is connected to a dry cell or an accumulator it acts like a weak bar magnet. You can use the compass to show that one end is a South pole and the other end is a North pole.



If you examine the coil you will see that the North pole end is the end where the current is flowing in the direction indicated by the upright lines in the letter N. The South pole end has the current flowing round it in the direction indicated by the ends of the letter S.

When some lengths of iron are placed inside the coil and a current passed through it, there is a stronger magnetic effect and the iron will pick up nails and other iron and steel objects just like an ordinary bar magnet does. When iron is magnetised in this way by a coil it is called an electromagnet.

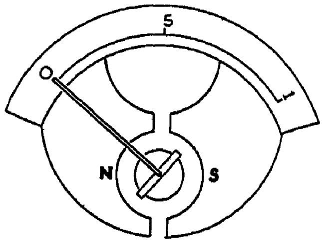
The more current you get in an electromagnet coil the stronger is the magnet. The more turns the coil has the

stronger will be the magnet. Therefore if you wind a coil on to a smaller former there will be a greater magnetic effect because the same length of wire will give more turns in the smaller coil.

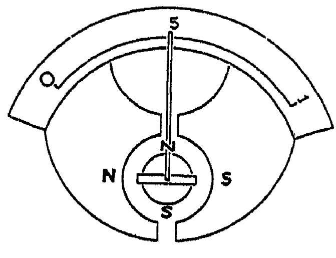
By putting a piece of steel into the coil instead of iron a permanent magnet is made when current is passed. Tapping the steel helps. To make a really good permanent magnet in this way, or a really strong electromagnet we need more electrical energy than we can get from dry cells or even from accumulators without a great expense.

METERS AND MOTORS

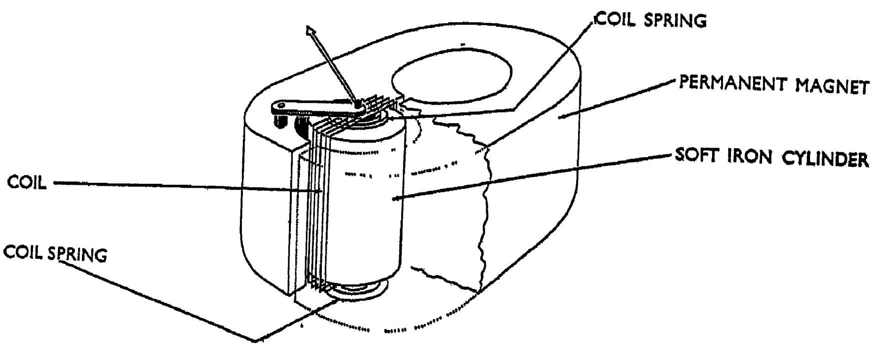
The fact that a coil with a current in it acts like a magnet which becomes stronger as the current is increased is used



NO CURRENT FLOWING

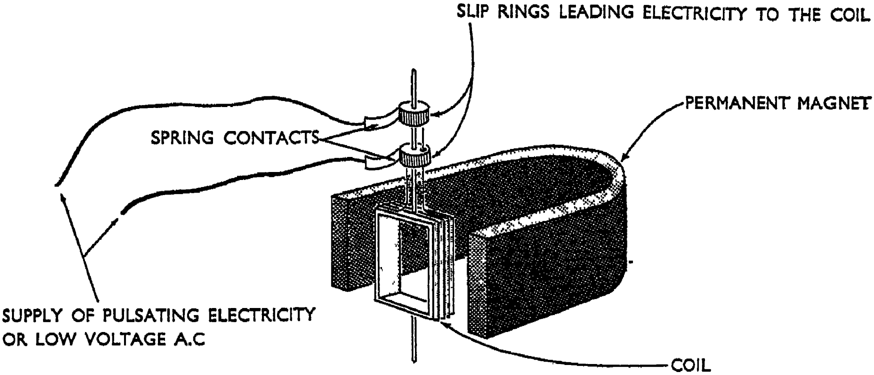


CURRENT FLOWING



in meters for measuring electrical current. The coil in a meter is pivoted between the poles of a permanent horseshoe magnet. When current passes through the coil it becomes a magnet which tries to twist into line with the poles of the permanent magnet, but is prevented from doing so by hair springs which hold it back. The more current flowing in the coil the stronger a magnet it will become and the further it will twist against the springs.

If we pivot a coil between the poles of a magnet so that it is free to keep turning, a current passed through it will

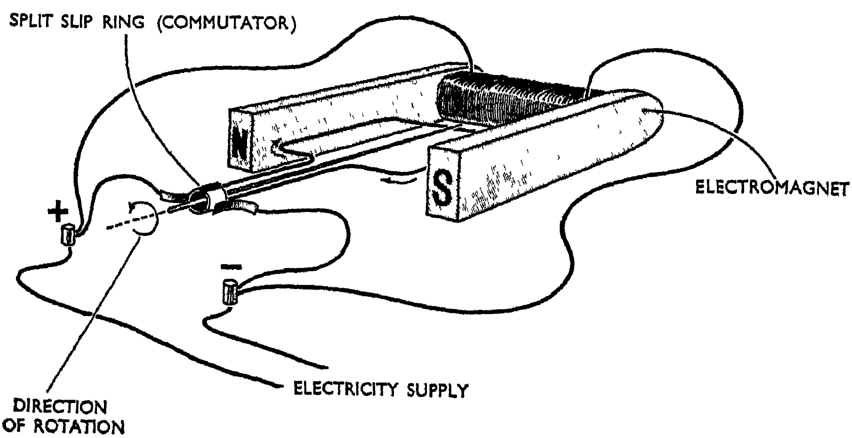


make it set with its North pole facing the South pole of the permanent magnet. If instead of passing a current continuously through the coil we used a tapping key which sends the current in pulses, we could, with practice, make the coil spin and keep it spinning. The use of alternating current which has a pulsing effect would also keep the coil spinning if we were to start it spinning in time with the current. The coil and magnet would make an electric motor.

An arrangement of coils and magnet like the one shown in the bicycle dynamo (page 136) would also make an electric motor. It would have the advantage that no slip

rings would be needed to get the current to the coil. Once again the magnet would have to be spun to make it move in step with the alternating supply, but once it was moving at the correct speed the electricity would keep it moving. Motors like this are called synchronous motors because they are always synchronised (or working in time) with the alternating current supply. Synchronous motors are used in electric clocks because they always rotate at a steady rate providing the frequency of the alternating current remains the same. Such motors can never be used on a D.C. supply.

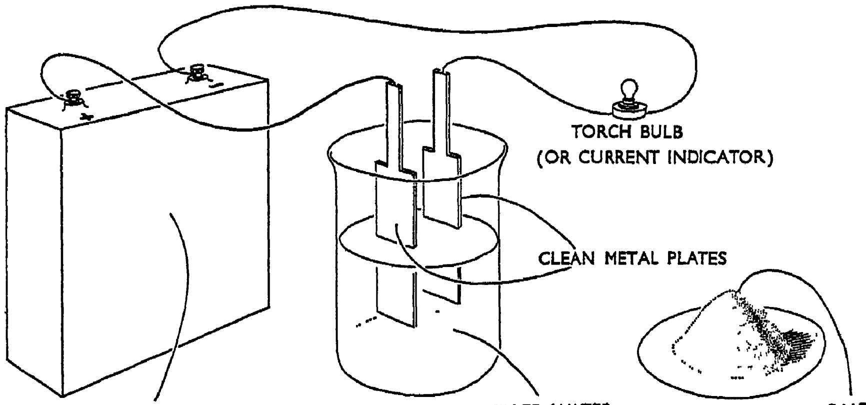
Other motors for use on A.C. and D.C. mains are more complicated because they contain a large number of coils and usually electromagnets instead of permanent magnets. The coils are not all used at one time and a switching arrangement has to be built in to arrange that the current goes through the right coils at the right time. The following diagram shows a very simple motor of this type. Large motors work on the same principle but are too complicated to draw simply.



LIQUIDS AS CONDUCTORS OF ELECTRICITY

So far we have thought of conductors of electricity as being solids, like the metals or carbon. Some liquids are also very good conductors. Mercury is, and so are many watery solutions. Pure water is practically a non-conductor of electricity, but when salts are dissolved in it the solution acts as a conductor.

This can be shown by connecting an accumulator in series with a torch bulb (or a current meter) and two clean metal plates which are in distilled water in a beaker.



The water is a non-conductor and no current flows, but if salt is dissolved a little at a time in it the bulb will begin to glow showing that a current is flowing. The current increases until the solution is saturated. Moving the plates nearer together allows more current to flow, and moving them further apart reduces the current. The bigger the distance between the plates, the bigger will be the resistance to the flow of electricity.

At one time salt solution in large earthenware pipes was used in theatres as a variable resistance for dimming the stage lighting. It still is used in some theatres.

ELECTROPLATING

If, in the experiment just described, the plate connected to the positive terminal of the accumulator is of copper, and the solution is of copper sulphate, you will notice a change taking place in the other metal plate as the current flows. It would become coated with a layer of brownish substance which can be shown to be pure copper. If you allow the current to keep flowing, the positive copper plate gradually becomes smaller, and the negative plate becomes bigger. Copper is moving from the positive plate (called the anode), through the solution, to the negative plate (the cathode). The process of plating an article with metal in this way is called electroplating.

Copper, nickel, chromium, silver and gold are metals which are commonly electroplated on to articles.

An electroplating method can be used for purifying metals. If a piece of impure copper is made the anode, and a small rod of pure copper is made the cathode in a solution of copper sulphate, copper from the anode passes through the solution and is deposited on the cathode leaving the impurities behind. Eventually we get a piece of pure copper at the cathode instead of a piece of impure copper at the anode.

Electroplating is also used for renewing worn metal surfaces in engines and machines. The old worn surface is plated with a coating of metal which can be machined to the original shape and size of the surface.

TEN QUESTIONS TO ANSWER

1. Explain why some materials conduct electricity better than others. What do we call a very bad conductor of electricity?

2. Draw and label a diagram to show what the inside of a torch cell looks like.

3. Draw diagrams to show (*a*) three torch cells connected in parallel and (*b*) three torch cells connected in series.

4. What is the connection between the resistance of a circuit, the voltage and the current flowing? What current would pass through a coil of wire with a resistance of 9 ohms if its ends were connected to a 3 volt battery?

5. What is the connection between watts, volts and current? What current is used by a 750 watt fire when it is connected to a 250 volt supply of electricity?

6. Why are fuses used in electrical circuits?

7. Describe how you could show that an electric current in a wire causes magnetic effects.

8. What is an electromagnet?

9. Explain why the coil of an electric meter turns when a current is passed through it.

10. What do we mean when we say that an article is electroplated?

THINGS TO DO

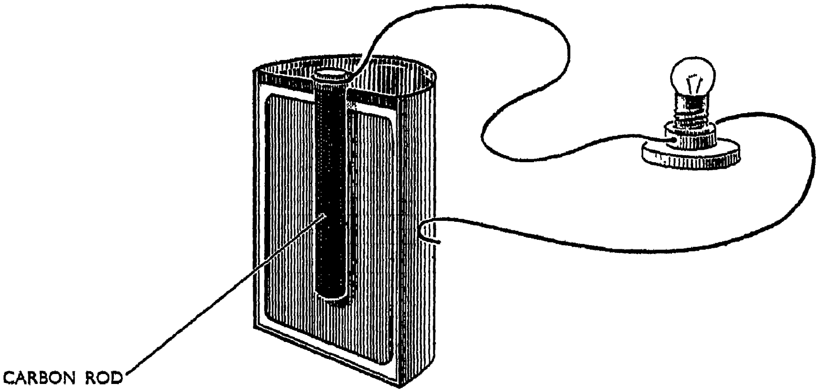
1. Carry out the experiments described at the beginning of the chapter to show that fountain pens can be charged electrically by rubbing them on the sleeve of your coat. (The empty cases of ball point pens are ideal for this experiment.)

Repeat the experiments using pieces of glass rod instead of fountain pens and a piece of silk instead of your coat sleeve.

2. Obtain a beaker, a carbon rod, a piece of zinc sheet and some dilute sulphuric acid and make up a simple electric cell. Connect the two plates by wires to a $1\frac{1}{2}$ volt torch bulb or to a meter to show that electricity is being produced. (Chemical energy is being changed into electrical energy.) Instructions for

making a simple but sensitive current indicator are given in No. 8 of "Things to Do." The indicator can be used in this experiment if you have no suitable meter.

3. Cut a new torch cell in half along its length but leave the carbon rod intact. The cutting is easily done with a hacksaw. Hold the cell in a vice and cut each side in turn to the middle. Test half the cell with a bulb. Does it give an electric current?



Testing half the cell

Now dry out thoroughly one half of the cell, place the carbon rod in it and test again with the bulb. Does it still give electricity? Splash water on the dry half to make it damp and test it once again. Is a dry cell really dry?

4. Obtain some old cycle and radio batteries and open them up to find out how the cells in them are connected together.

5. Ask your father or mother to show you the fuse boxes in your home. Make a drawing of the main cable coming into your home, the company's fuses, the meter or meters and the house fuse boxes to show how they are all arranged.

Find out the sizes of the fuses used and work out the wattage of apparatus you can safely connect to each circuit in your home.

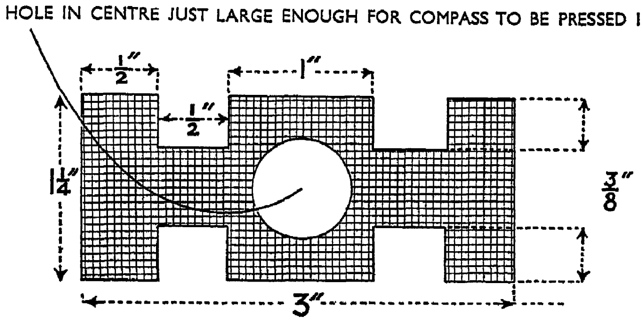
6. Make an electromagnet using a 6 in. nail or a bundle of pieces of iron wire about 6 in. long.

7. Obtain two lead plates about 4 in. long by 1 in. wide and

make up the simple accumulator described in this chapter. Connect it to a dry battery for 15 to 30 minutes and watch the changes which take place.

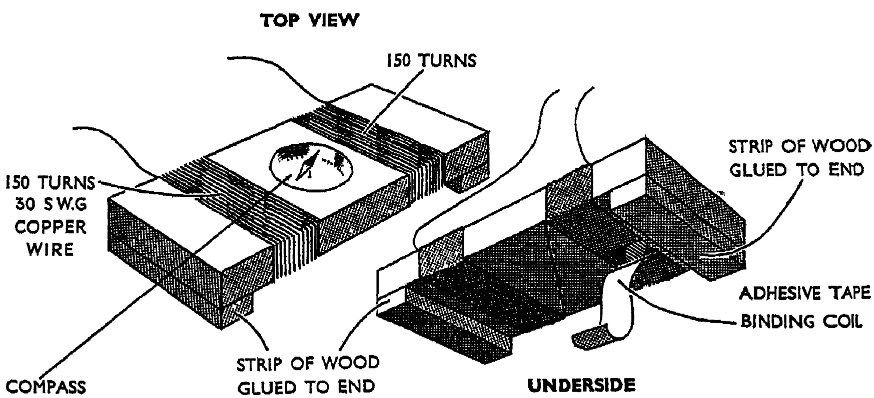
Disconnect the battery and connect the accumulator to a meter or current indicator. Has it stored electricity from the dry cells?

8. *A Simple Current Indicator.* You require a piece of wood about 3 in. by 1¼ in. by ½ in. in size, a small pocket compass about



¾ in. in diameter and some 30 S.W.G. insulated copper wire. Plane the wood until it is the same thickness as the compass, then cut it to the pattern shown above.

Wind 150 turns of wire round the narrow neck at one end, take the wire across the back of the wood and then

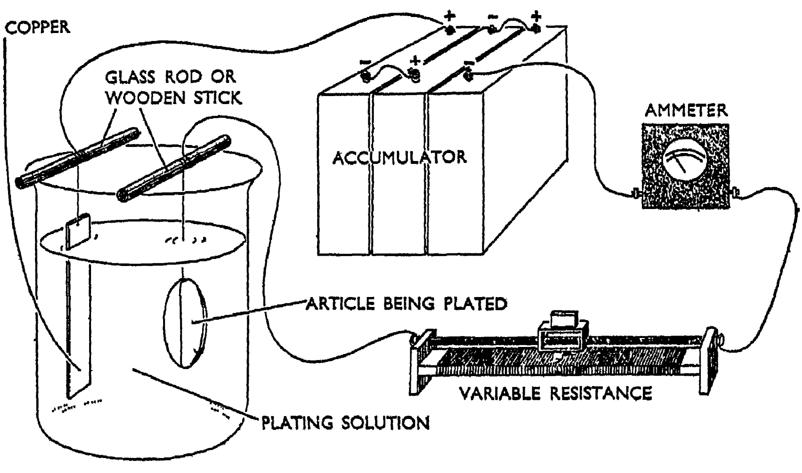


wind 150 turns on the other narrow part. Wind in the same direction in both cases.

Bind the coils in position with adhesive tape. Stick a piece of white paper on the underside of the middle part and glue a strip of wood across each end.

This instrument will indicate quite small electrical currents. It should be set on a bench with the compass needle at right angles to its length.

9. *Copper Plating.* You will require a large beaker or glass trough, an ammeter, a variable resistance, a sheet of copper, accumulators or other low voltage supply and the plating solution.



The plating solution is made by mixing $\frac{3}{4}$ fluid ounce of concentrated sulphuric acid into 1 pint of distilled water (your teacher must do this if you are not used to handling strong acids), and then dissolving $\frac{1}{4}$ lb. of copper sulphate in the dilute acid. On the metric system these proportions would be 400 cubic centimetres of distilled water with 15 cubic centimetres of concentrated sulphuric acid and 80 grammes of copper sulphate added. This quantity would be enough for a large beaker, but you would have to make up more for a trough or tank.

The article to be plated should be thoroughly cleaned to

remove dirt and grease and then rubbed hard all over with a damp cloth and pumice powder. A well cleaned toothbrush is useful for getting into crevices. When the article is clean it should be washed under a tap and then placed in the plating bath. The diagram opposite shows how to set up the apparatus.

The temperature of the solution should be 15° C. and the variable resistance adjusted so that one tenth of an ampere of current is allowed to flow for each square inch of the surface being plated.

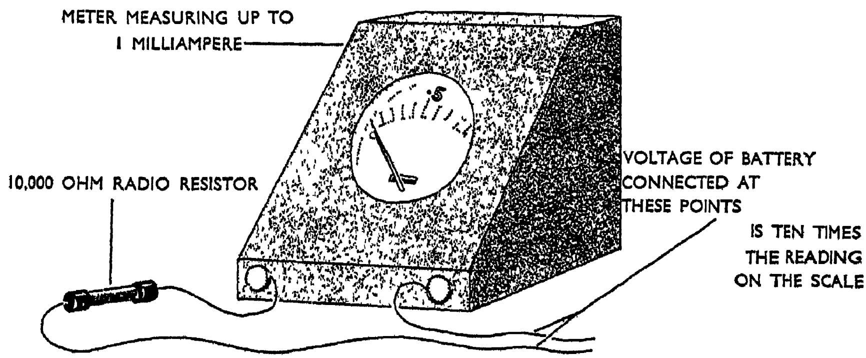
When you can copper plate an article successfully read about electroplating in books and find and try methods of plating with other metals than copper. Make a list of all the uses of electroplating you discover in your reading.

10. *Meters.* To explain how you can adapt any meter you may possess to give different voltage and ampere readings we give the following example using a 1 milliampere meter. This type of meter is very common and can be obtained cheaply in many stores selling secondhand equipment.

The resistance which, connected to a 10 volt supply, would only allow a current of ·001 ampere (1 milliampere) to pass through it is given by dividing the voltage by the current in amps.

$$\text{Resistance} = \frac{\text{Volts}}{\text{Amps}} = \frac{10}{\cdot 001} = 10{,}000 \text{ ohms.}$$

An ordinary radio resistor of this value connected to one



1 milliamp = $\frac{1}{1000}$ amp = ·001 amp

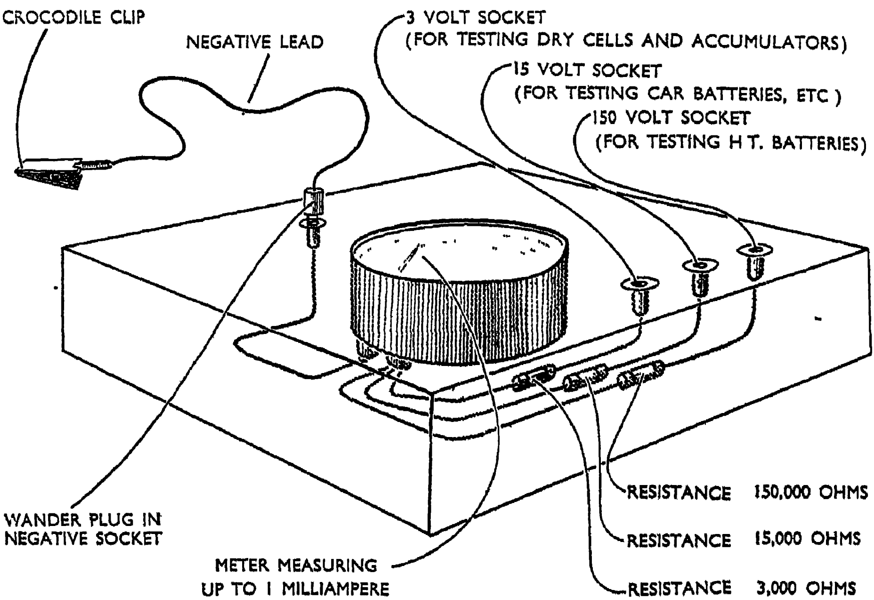
terminal of your ammeter will turn it into a voltmeter reading up to 10 volts.

For greatest accuracy the total resistance of the resister you connect plus the resistance of the meter coil should be 10,000 ohms, but for general work this is not worth worrying about. The resistance of the coil in a meter is usually marked on the face.

Whatever the highest voltage you want to measure, that voltage divided by the full scale current of the meter is the resistance you connect in series with the meter.

By fitting the meter and resistances into a box you can make an instrument which will measure voltage over quite a wide range.

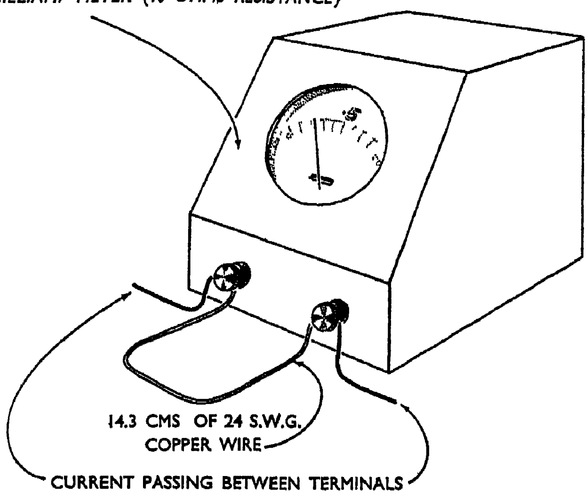
If you want to make your milliammeter into an ammeter which will measure up to 1 amp, you will want a shunt which will take 999 milliamps leaving the odd 1 milliamp to work the meter.



A three range voltmeter

The positive lead is plugged into the socket whose range contains the value of the voltage being tested. When in doubt start from the highest range and work downwards

You will need a shunt with a resistance $\frac{1}{999}$ of the resistance of the meter. This is near enough to $\frac{1}{1000}$ for practical purposes and if the resistance marked on the meter is 10 ohms, the resistance of the shunt you require will be $\frac{1}{1000} \times 10 = \cdot 01$ ohms. If you look at wire tables you will find that a 24 S.W.G. copper wire will take 1 amp of current safely and that it has a resistance of ·07 ohms per metre. One seventh of a meter or 14·3 centimetres of this wire will have the resistance and current carrying capacity you need for your shunt.

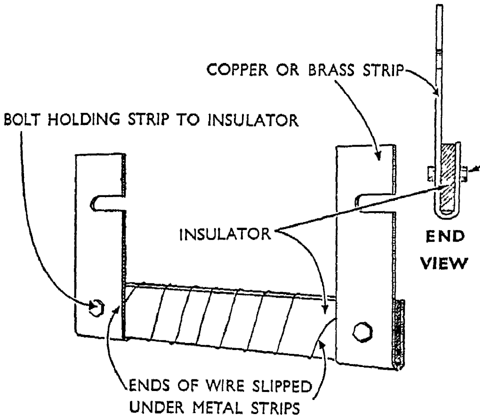


See if you can work out why a shunt to allow you to measure up to 10 amps on this meter would have a resistance of ·001 ohm. This shunt could be a piece of 14 S.W.G. copper wire 18·5 centimetres long or a piece of 12 S.W.G. copper wire 31·3 centimetres long.

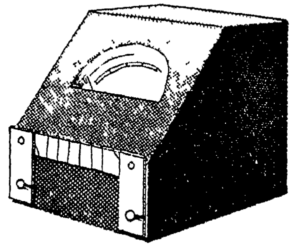
The shunts should be wound on to strips of insulating material with copper or brass strip connectors at the ends which can be screwed under the meter terminals. Wood or stout cardboard could be used as the insulating material.

The simplest way of checking the accuracy of the shunts you

make is to see if your meter with a shunt on gives the same readings as a good commercial meter like the Avo or Taylor meter. If your meter reads too high the shunt wire is too long and if your meter reads too low the shunt wire is too short. Mark each made up



SHUNT MADE UP



SHUNT IN USE

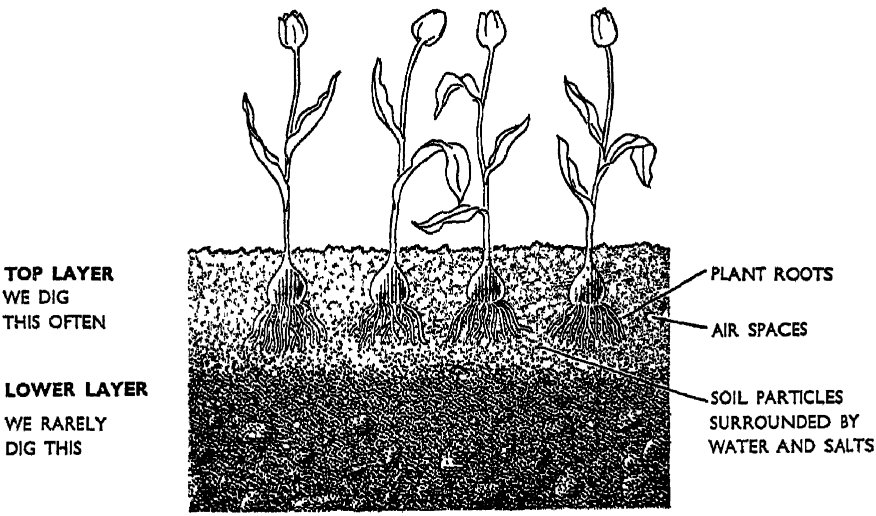
shunt with the current the meter can read when the shunt is in use and with the figure by which you multiply the meter reading to give you the true value of current flowing.

CHAPTER 11

Working in the Garden

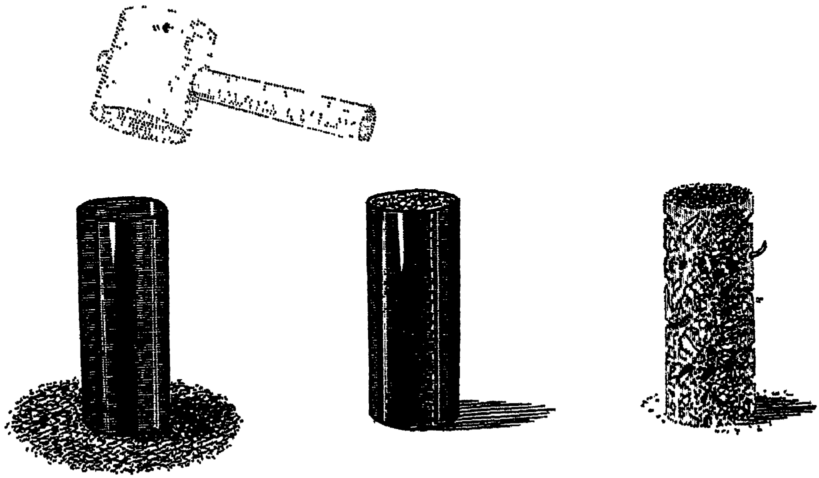
The soil

Good garden soil, which we often call loam, is made up of rock particles, air, water, leaf mould (sometimes called humus), and salts. If you could cut down into the soil it would look something like this:



It will be easier for you to remove some of the top soil and examine it in its natural state to see what it is like before you break it up by digging. With a tin opener, remove the bottom from a cocoa tin. Also take off the lid. Hammer the tin into the soil. Dig out the tin, cut it with metal snips to get out the block of soil. What is it like?

Feel the soil with your fingers, and see how easily it crumbles. Notice its dark colour.



1. Hammer the tin into the soil

2. Dig it out and cut the tin with snips

3. Notice the large air spaces. What else can you see?

Some other kinds of soil

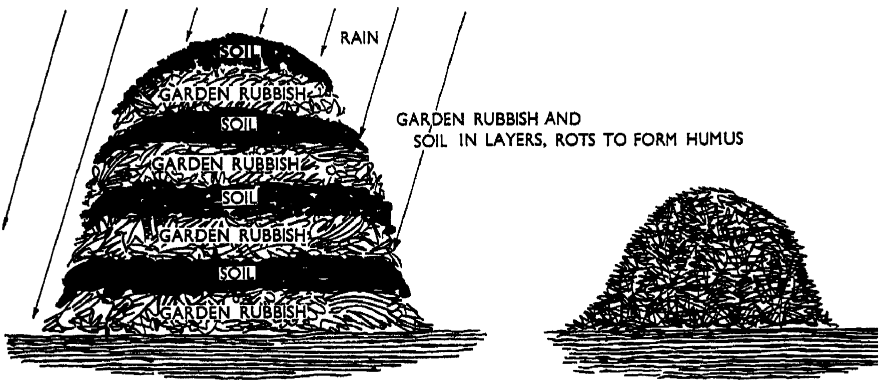
Clay soil is sticky, heavy to dig, waterlogged in wet weather, contains little air, cracks in dry weather.

You can improve a clay soil by adding lime. Lime joins the small clay particles together to form larger ones. These bigger "crumbs" have larger air spaces between them and so the soil is now easier to dig and to drain. You will find some experiments to do with clay soil, on page 180. A chemical called Krilium also breaks up clay into crumbs. It is at present much more expensive than lime but its effect lasts longer than that of lime. Look out for more news about Krilium. Your teacher may get a small amount from the horticultural stores for you to experiment with.

Can you think out some experiments to compare its action with that of lime?

Sandy soil does not hold water so plants die in it in dry weather. We dig humus into sandy soil because humus holds water well.

Humus is dark brown, is spongy and it holds much air and water. Farmyard manure rots and makes humus. Garden rubbish mixed with soil in a compost heap also rots to make humus. Useful bacteria in the soil rot the



A COMPOST HEAP

HUMUS

rubbish if the heap is kept moist. You can buy a mixture from a horticultural stores which will speed up the rotting of garden rubbish to make humus. Later the humus rots and provides the soil with useful salts.

Salts in the soil

Shake up a little garden loam with rain water or distilled water, let it stand for a few hours and filter off the liquid. Evaporate this colourless liquid to dryness in an evaporating basin. Notice the whitish-brown crust that is left on the basin. Do you get this stain when you evaporate filtered rain water? The crust is made up of soil salts

which were dissolved in the water in the soil. Some of these salts are nitrates, phospates and sulphates. You can find out more about the value of these salts to plants if you carry out the experiments on page 187. Some members of the class might shake up some sandy soil with rain water, and some might use clay soil or chalky soil. If you all use equal weights of soils which you have left in the air to dry for several days, you will be able to compare the amount of salts in the different soils. Which soil has most salts? Which contains least?

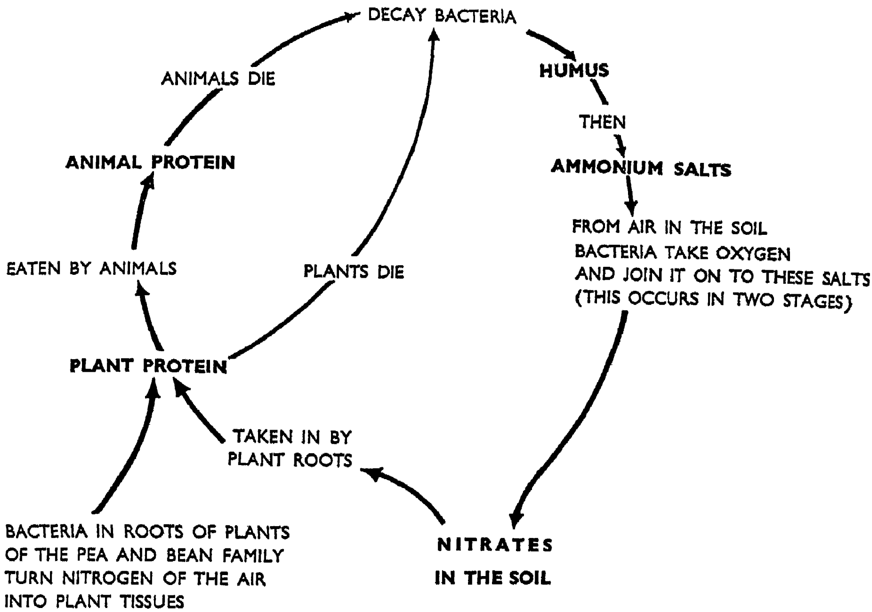
Fertilisers

The plants we grow use up salts from the soil. When we use these plants for food, the salts do not get back to the soil, so if you are growing fruit and vegetables or flowers for cutting, you will sometimes need to add useful salts to the soil to make up for those which are lost. You can give the soil a dressing of such fertilisers as compost, farmyard manure or peat, or you can use "artificial fertilisers" such as a carefully prepared mixture of the salts chemists have found in the soil. You can buy one of these mixtures at your seed shop. Take great care to follow the instructions exactly. You will see what happens if you use too much, when you do the experiments on watering plants with solutions of salts (page 187). Some gardeners use such fertilisers as "dried blood" and bone meal because they rot down slowly and supply the plants with just enough salts all the time for several months.

How salts are put back into the soil in natural ways

We will take one of the most important kinds of salts, the nitrates, and see how the natural supply is maintained. You will notice that the work is done by different kinds of

useful bacteria in the soil. These bacteria can live only in well aerated soil. If the soil becomes waterlogged, another kind of bacteria gets to work and destroys the nitrates.

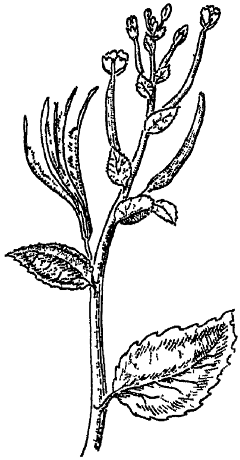


This is one good reason why we should dig and drain soil well.

Looking after the soil

You must look after your soil well if you want to get good healthy crops. This is known as good cultivation. The more we know about the soil the better we shall be able to cultivate it.

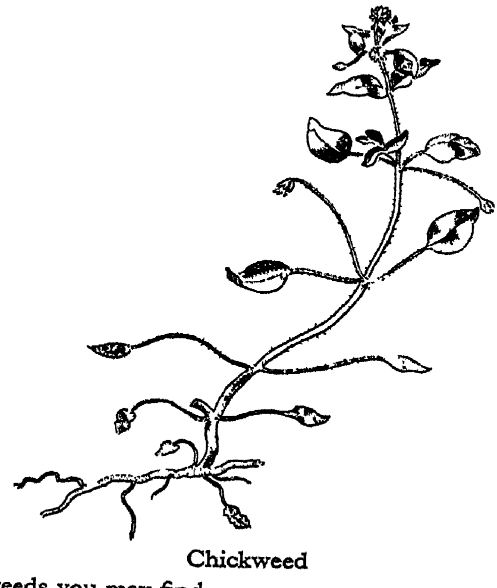
Digging. The roots of plants, and animals such as the earthworm need to use oxygen from air in the soil. Dig the soil well to trap air in it. Do not bury the top soil. It contains most humus. In the lower layers of soil there is



Willowherb

Groundsel

Dandelion



Chickweed

Some weeds you may find

less air, less humus, more salts and more water than in the top layer. The water and salts can rise up to the top layer in loam and in clay soil.

Weeding. Weeds are plants which grow where we do not want them. A dandelion is a weed on the lawn but not on a piece of waste land. Weeds are harmful because they use up water and salts, they grow quickly and shut out light from the garden plants, and they often carry plant pests and diseases. Pull up larger weeds and hoe the ground often to remove weed seedlings. Many weeds have seeds which are carried miles by the wind, and they can remain alive in the soil for many years, so remember to "keep the hoe moving." On the lawn you might like to experiment with one of the selective weed killers from the horticultural stores. Notice which weeds are killed first and how long it takes for each kind of weed to die. Are there any weeds which are not killed? Can you discover any differences between these weeds and the others? Can you discover why the grass is not killed? Try to think this problem out first, then read the notes on the bottle.

Testing the soil for acid. Many plants do not grow well in soil which is too acid. We say that such soil is "sour." Some plant diseases, for example, the "finger and toe" disease of the cabbage family of plants, thrive in acid soil. If we find that the soil is acid we add lime to it. Lime neutralises the acid because it is an alkali. Soil indicator can be bought from some horticultural stores. It is a green liquid. Use it to perform the experiment on page 161.

Tip the saucer after a few seconds and notice the new colour of the indicator. If the indicator is now red, the soil is very acid, if yellow it is slightly acid. Most plants grow well in such a soil. The indicator stays green if the soil is neutral, and it turns blue if the soil is alkaline. Your soil needs liming if the indicator turns red or orange. Test the

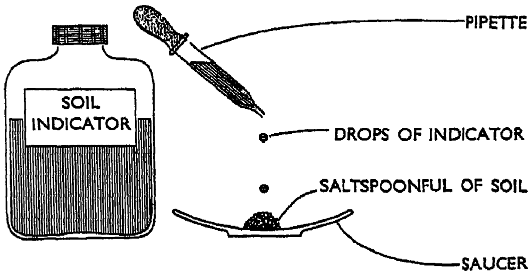
Shepherd's purse

Woody nightshade

Daisy

Some weeds you may find

soil in different parts of the garden as it may vary from place to place.



Testing soil for acid

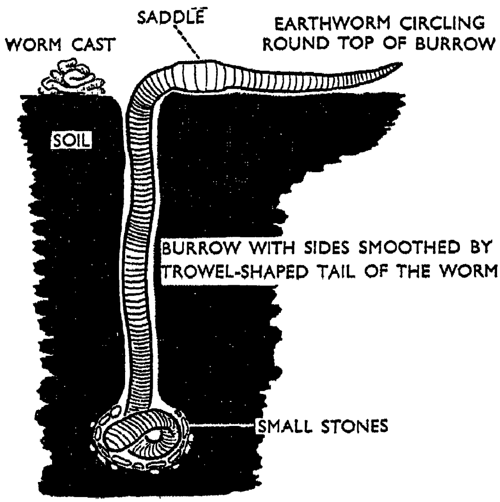
How much lime should you add? Slaked lime is used as a rule. If quicklime is used, only two thirds of the amount is needed.

Soil turns indicator	*Slaked lime (ounces per sq. yd.)*		
	Sandy soil	*Loam*	*Clay soil*
Orange	7 oz.	10 oz.	14 oz.
Red	9 oz.	12 oz.	16 oz.
Dark red	10 oz.	16 oz.	20 oz.

How earthworms help to improve the soil

Earthworms live in the top layers of the soil because they feed on humus. Can you think why there are very many in a compost heap? Often they have to eat the soil to get the humus from it. As the soil passes through their bodies, it is crushed and mixed with a chalky substance which neutralises any acid in it. At night when earthworms come out of their burrows, this soil is deposited on top of the ground as worm casts. When these are dry, they form fine soil which is very good for growing seeds.

The burrows of earthworms drain and aerate the soil. By taking down dead leaves and bringing up soil to the surface, they mix up the soil and humus. For this reason Charles Darwin, a famous biologist who lived in the last century, said that earthworms are responsible for covering over Roman remains. Year after year they remove soil from underneath the ruins and deposit it on top of them. He



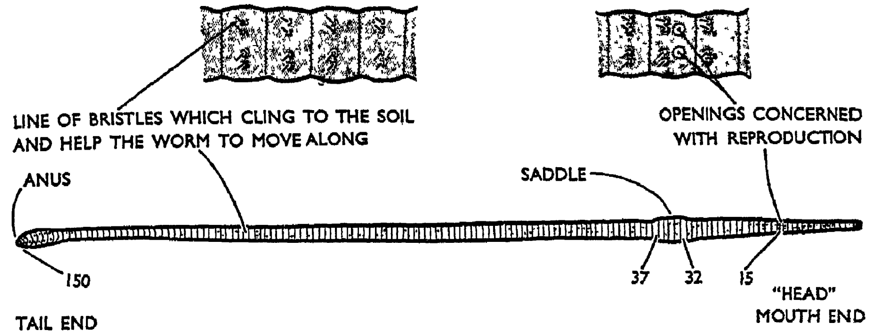
thought that earthworms bring $\frac{1}{10}$ in. of soil to the surface as wormcasts each year. Earthworms are the gardener's friends and should not be killed.

Earthworms take in air through their moist skins. If the skin dries, the worm dies. In dry weather they tunnel deeper into the soil to moister layers.

Studying the earthworm

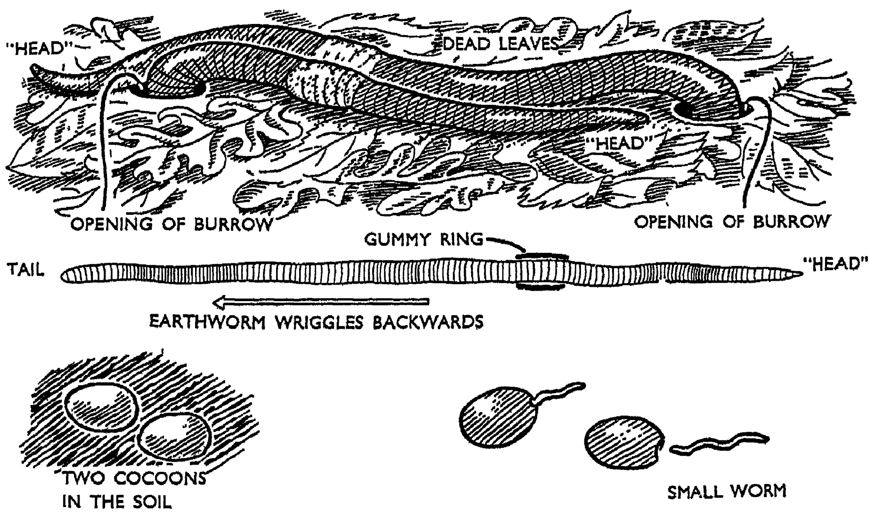
Look carefully at an earthworm and try to find all the parts labelled in the drawing. Put it on a piece of rough

paper and watch it move. Describe how it seems to move forward. Can it move as well if you place it on a piece of glass?



Under side of the earthworm (× ½)

The saddle is connected with reproduction. It produces a gummy substance which keeps two earthworms together

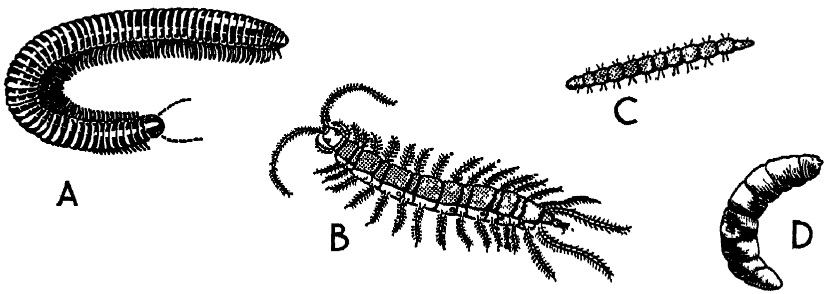


How new earthworms are produced
(*Above*) mating (× 1) (*Centre*) Forming the cocoon (× ½)

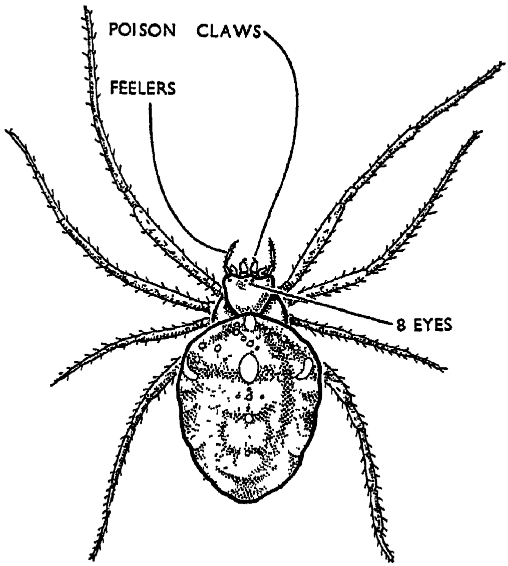
while they are mating. Although each earthworm produces both eggs and sperms, during mating each worm transfers sperms from segment 15 of its own body into storage pores in the body of the other worm. The worms separate, then the saddle produces a gummy ring which hardens as the worm wriggles backwards through it. Eggs and also the sperms received from the other worm are deposited in the ring and then the ends of the ring close up to form a cocoon. Inside this cocoon the fertilised eggs hatch to tiny white or yellow worms. Young worms have no saddle. Can you think why?

Some other creatures you may find in the garden

Earthworms, beetle larvae, snails and ants can be kept in the science room in the apparatus you learned to make for them in Books I and II. Look in apples for the caterpillars of the Codlin moth. These maggoty apples often fall early. As the fruit develops the caterpillars hatch and feed on them. When the insect is ready to form its crysalis, it bores its way out of the fruit, and pupates in a crack in the bark. The adult moths emerge next year when the trees are in flower. We can spray with chemicals to kill them and other insect pests.

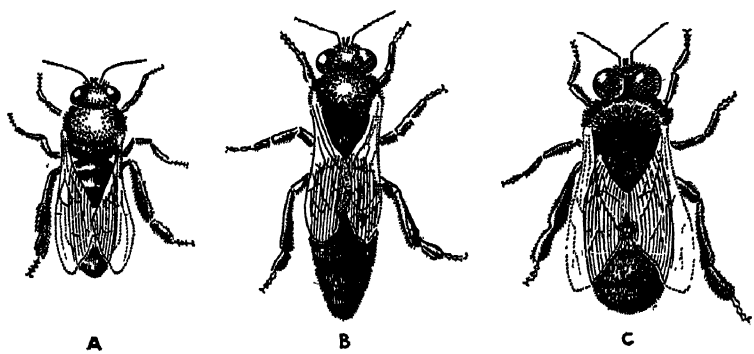


A. Millipede B. Centipede C. Leather jacket D. Beetle larva



The Garden Spider

Bees. Worker bees visit flowers and obtain the sugary juice, nectar, from them. They store it in a nectar bag and take it back to the hive. Pollen is collected and taken to the hive in pollen baskets on the hind legs. You can watch the



A. Worker B. Drone C. Queen

bees collecting these foods in the garden or park on a summer's day. As the bee flies from flower to flower, it takes pollen from one flower to another and so pollination occurs. The best known bees are the hive bees. In each hive there is a queen, many workers and a number of drones or male bees. The queen lays eggs in wax cells made by the workers. The workers also look after the young, collect food, make honey from nectar, keep the hive clean, and fight enemies by stinging them. Keeping and studying bees is a good hobby. You will be able to borrow books on bee keeping from your library.

Greenfly, slugs and snails are harmful in the garden. Greenfly are insects which suck sap from plants through a sharp tube-like mouth. They carry virus diseases from one plant to another and so should be destroyed by spraying. Look for "cuckoo spit" on plants. You will often find greenfly living in ants' nests. The ants milk the greenfly as we milk cows. Sometimes ants climb plant stems to reach the greenfly.

The temperature of the soil

Does soil temperature vary with the seasons? For part of the Winter, soil temperature is too low for roots to absorb water (see Book I). As the soil temperature rises, water can be absorbed and growth can begin again. In different parts of the garden make holes with a pencil about 1 in. deep and place the bulb of a thermometer in each hole for five minutes. If you do this at the same time on one day every week from January until June, and keep your results, you will see whether soil temperature and the amount your plants grow are related.

Does soil temperature vary with the slope of the ground

and the "aspect"? Repeat this experiment on North and South slopes. What do you find?

Does the colour of the soil affect its temperature? You will remember that dark colours are good absorbers of heat. (Chapter 7.) See if this is also true for soils. Fill a six inch flower pot with black garden loam, fill another with loam mixed with slaked lime to give a grey colour, and another with silver sand. Leave them in a sunny position side by side and note the temperature of each soil at a depth of 1 in. every day for a week. Do not forget to record whether the day is sunny, wet, or dry but overcast.

Does the soil temperature differ on the shady side of a tree and on the sunny side? Make up an experiment to find out the answer.

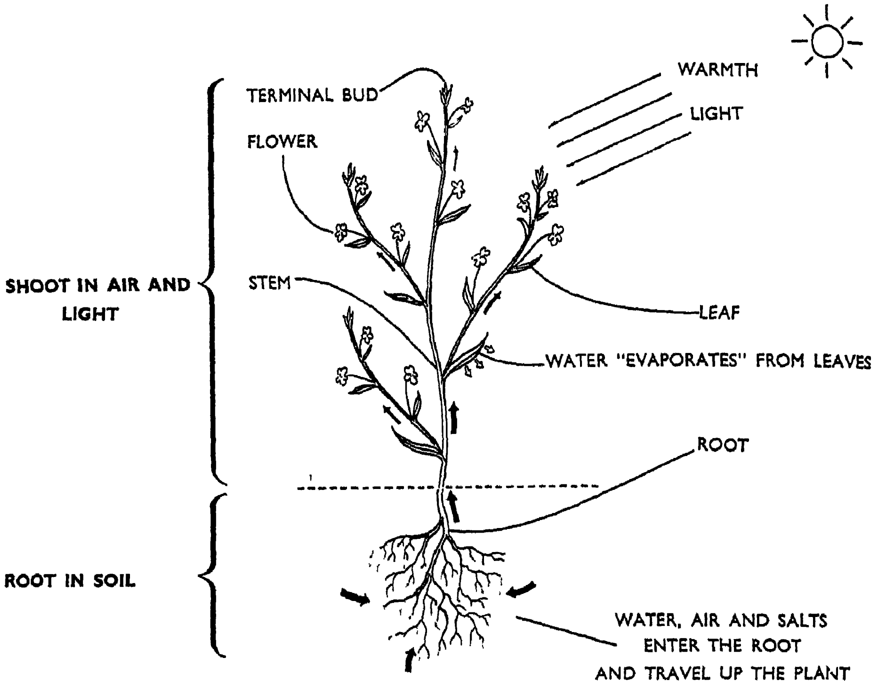
Plants in the garden

Trees and shrubs have a hard woody skeleton. Herbaceous plants have soft green shoots with only a little wood.

The life of plants

Time they live	*Name*	*Kinds of plants*
1 year or less ..	Annuals	Many weeds, poppies, candytuft
2 years ..	Biennials	Carrot, snapdragon, mullein
3 years or more ..	Perennials	Trees, rose bushes, chrysanthemums

Parts of a plant and their work

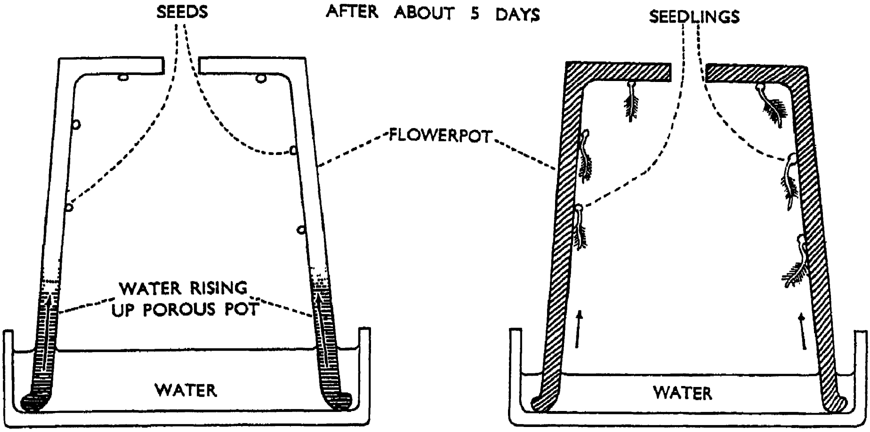


Some facts to remember

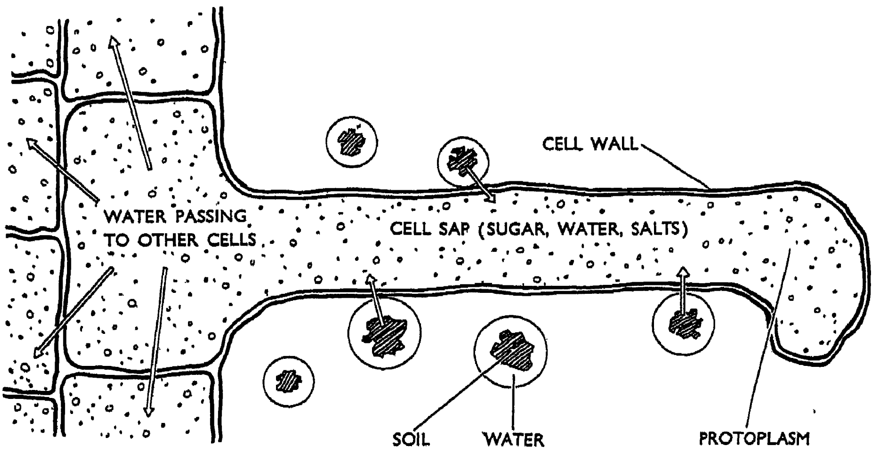
1. *The Root* fixes the plant in the soil and takes in water and mineral salts.
2. *The Shoot* consists of stems, leaves, buds, flowers.
3. *Green leaves* make food in sunlight. They give out water as water vapour.
4. *Buds* grow into new shoots or flowers.
5. *Flowers* are reproductive shoots. They make seeds.

How the root takes in water

Sprinkle some cress seeds inside a wet flower pot and leave for a few days over water.



Each root hair is one rather large cell. If we put one under the microscope it looks like this:—

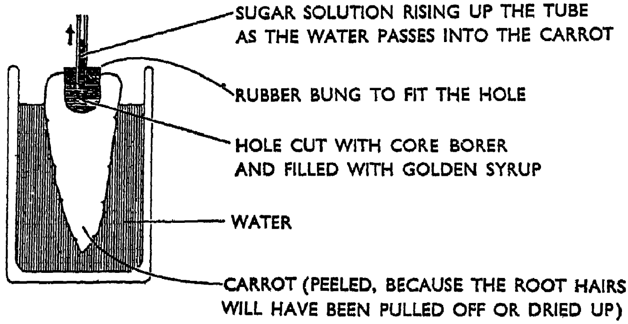


One root hair under the microscope

Transplanting. When you wish to move a plant, always dig it up with some soil round the roots. Pulling up a plant

tears the root hairs and the plant may die before it can make new ones. Always press the soil down firmly after transplanting.

Try this experiment with a carrot and see how much water it takes in.



A root taking in water

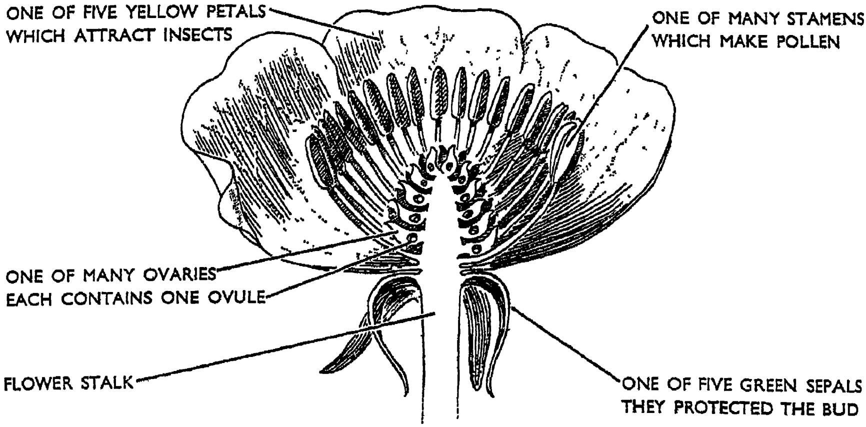
Salts from the soil get into the root hairs by diffusion. (Book I.) Inside the plant some salts join on to the sugar made by the green leaves and make another food, protein.

Parts of plants we use for food

NAME OF PLANT	PART USED AS FOOD
Cabbage	A large bud
Carrot and parsnip	Swollen root
Pea and bean	Seeds
Rhubarb	Leaf stalk
Celery	Leaf stalk
Potato	Swollen underground shoot
Apple, orange, cherry, tomato, cucumber	Fruits
Spinach	Leaf
Onion	Bulb—underground bud
Nuts	Seeds

Flowers

Find these parts in a buttercup flower:—



A buttercup flower cut from top to bottom (×3)

Look at some buttercup pollen under the microscope. Notice the tiny bumps on it which help it to stick to insects' bodies. (Pollen carried by wind is smooth.)

How seeds are formed

In Books I and II you learnt that the small ovules in the ovary each contain a female egg cell. The pollen grain contains a male cell. The pollen sticks to the stigma and grows a tube down to the ovule. Inside the ovule, fertilisation takes place.

Then the fertilised ovule turns into a seed.

The ovary ripens and becomes a fruit.

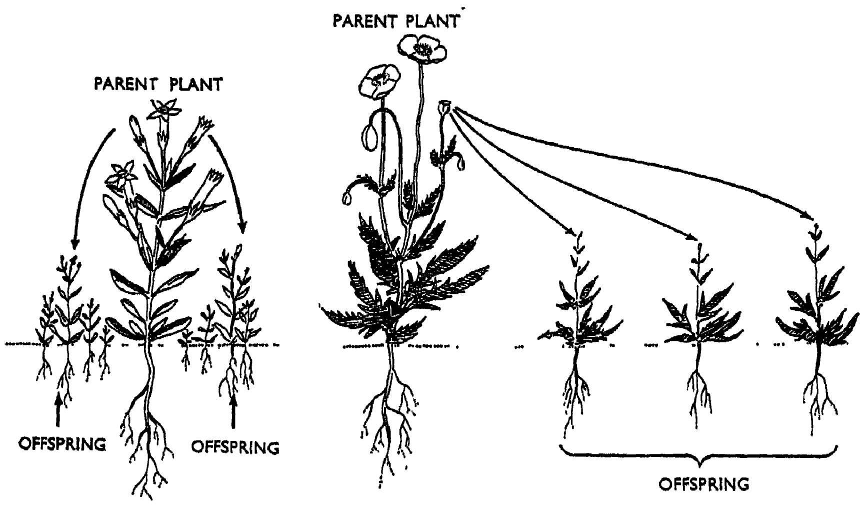
Not all fruits are juicy. Some are hard, like nuts, and some, like poppies, are brittle and dry.

The scattering of seeds

We collect ripe seed and plant it where we want it to grow. In Nature, seeds are scattered by wind, animals or by explosion of the dry fruit.

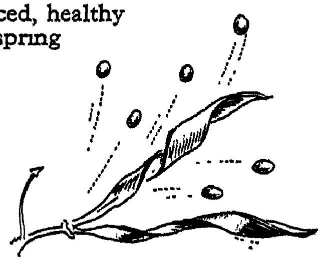
If seeds drop close to the parent plant, the seedlings are often unhealthy because they are overcrowded. They have little room to grow, and little light, water and mineral salts.

If seeds are scattered by explosion of the fruit or by wind or animals, they usually have plenty of room to grow. They have a good chance of becoming healthy plants if they have enough light, water and mineral salts.



Overcrowded unhealthy offspring

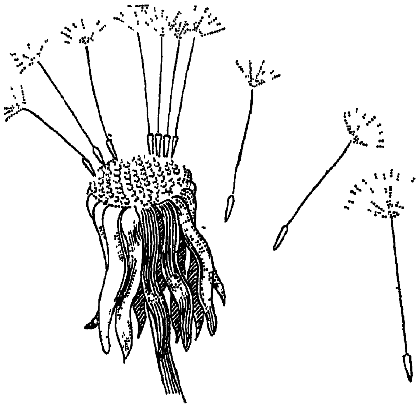
Well spaced, healthy offspring



How seeds are scattered

1. *Sweet Pea* explodes and shoots out the seeds.

2. *Dandelion* has a parachute which can sail through the air.

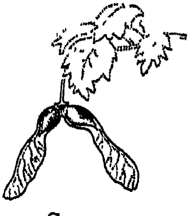


Dandelion

3. *Sycamore* has a wing. It can sail through the air.

4. *Geum* has hooked seed cases. They stick in coats of furry mammals.

5. *Hawthorn* has juicy red seed cases. Birds eat them and may carry seeds in their bodies for miles. Hours later the



Sycamore

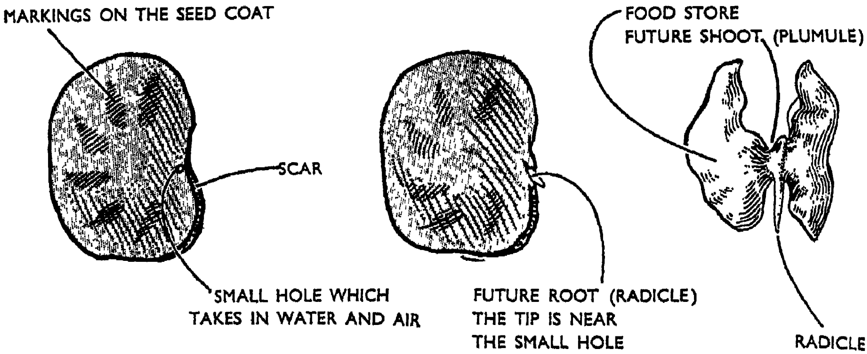
Geum

Hawthorn

seeds are left on the ground in the bird's droppings. They will grow more quickly than those which fell from the tree because the acid in the bird's gut softens the woody seed.

PARTS OF A SEED

Examine a soaked runner bean seed. Look for the parts shown in the drawings. Most seeds have these parts.



Outside view (×1) — The seed with the seed-coat removed (×1) — The seed leaves opened out (see Book I)

The runner bean seed has a *radicle*, a *plumule*, and two seed leaves or *cotyledons*. We call all these things together, the *embryo*.

Now look inside the seed coat. Can you find the small pocket in which the radicle was placed?

The Growth of Seeds—Germination

While we keep seeds dry they do not grow. In moist soil they *germinate* or begin to grow. Here are some experiments for you to do to find out what conditions are necessary for germination. Take five small flower pots and a beaker of about the same size. Obtain some good garden

soil, dry it and crumble it with your fingers. Put one or two stones at the bottom of each pot, fill the pots and the beaker with soil almost to the rim and place each pot on a saucer. Number the pots 1 to 5.

Do seeds need water? Place 20 mustard seeds on the dry soil on pot 1. Do not water.

Do seeds need light? Place 20 mustard seeds on top of the soil in pot 2. Water well. Place 20 seeds in pot 3, then cover them with soil so that they are in the dark. Water well.

Can seeds grow when the soil is cold? Place 20 seeds on the soil in pot 4. Water well. Place the pot in a refrigerator for a week, or if it is Winter, leave the pot out of doors.

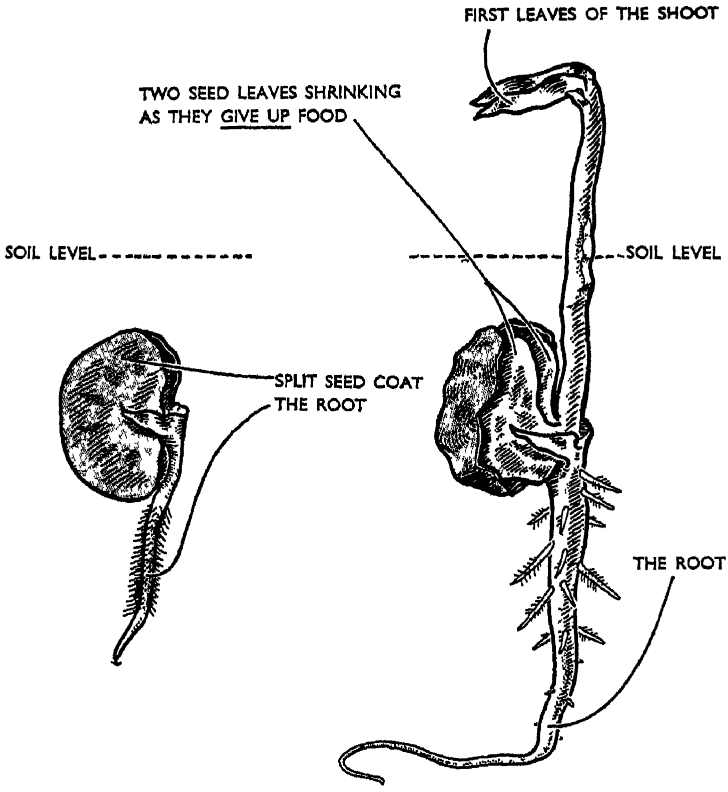
Do seeds need air? Place 20 seeds on the soil in the beaker. Pour enough cold *boiled* water on to the soil to fill the beaker. (Cold boiled water contains no air. Why?)

Do seeds germinate if they have water, air and the temperature of the science room? Place 20 mustard seeds in pot 5. Water well and keep in the warmest part of the room, beside pots 1, 2 and 3 and the beaker. Count the number of seeds in each pot germinating in a week. One group of pupils might use marigold seed, another cabbage seed, etc. You may like to see if boiled seeds will germinate, or if seeds which have been refrigerated will germinate afterwards. What have you found your seeds need in order to germinate?

How seeds germinate

Most seeds germinate in the same way as the runner bean or the mustard. In the Scarlet Runner Bean the seed leaves stay below the ground and gradually give up the food they contain to the growing seedling. In the mustard and lupin, the seed leaves come above the ground and are

the first green leaves. These first leaves are often very different in shape from the later leaves.



Germination of runner bean (× 1)

Grow many kinds of seeds in seed boxes or flower pots. Notice the different sizes and shapes of seeds. Sprinkle small seeds on top of the soil; plant larger seeds about 1 in. down in the soil. If you first count the number of seeds you plant, you can find how many germinate each day and how many of each kind germinate altogether. You can then

work out the percentage germination as the seedsman does. Write down the names of seeds which finish germinating within a few days of sowing and those which go on germinating for several months. Can you think of advantages and disadvantages of these different habits? You may find seeds which germinate only after being in damp soil for over a year. Some seeds such as the black seeded varieties of Sweet Pea have a hard seed coat. Gardeners chip the seed coat on the side away from the scar to hasten germination. Can you think why this helps? Why must they avoid damaging the region of the scar?

Seed sowing and the moon. You may have heard people say that seeds germinate better if they are sown when the moon is full. Can you think out an experiment to test if this is true?

Does "old" seed germinate as well as fresh seed? If you can find some cabbage or parsnip seed left from last season or the season before, compare the percentage germination of this stale seed with that of fresh seed. Use about 100 of each kind of seed. Plant each kind in a large flower pot and count and remove the seedlings as they appear. Stale seed of the garden stock is said to have a lower percentage germination than fresh seed, but you are more likely to get plants with double flowers from the stale seed. You may be able to test this out for yourselves. Assuming that every batch of seed contains some seeds which will give stock plants with double flowers, can you think out a theory to explain why doubling *seems* to increase with the age of the seed?

Multiplying our plants without growing seeds

We can often break up plants to increase the numbers. Here are some ways of increasing your favourite plants.

1. *Grafting* (Fruit trees).

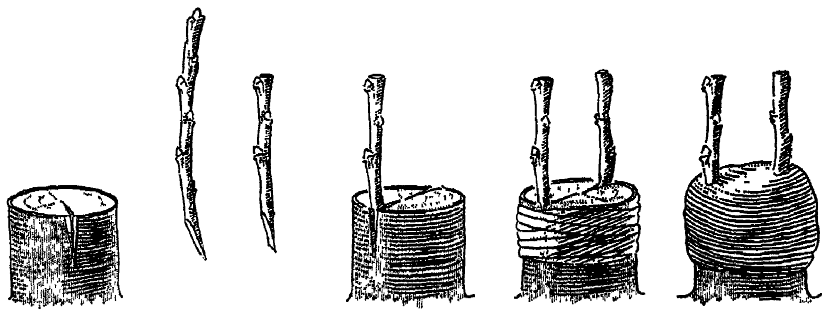
2. *Breaking up the roots* (Phlox, thrift).

3. *Runners* (Strawberries).

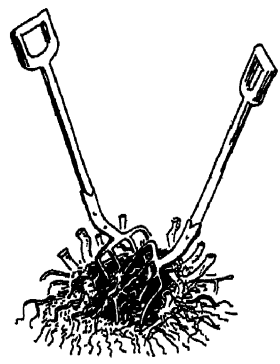
4. *Planting single swollen roots* (Dahlias) *or swollen stems* (Potatoes).

5. *Planting underground buds (bulbs)* (Daffodils, Shallots) *or underground stems* (Crocus corms).

6. *Breaking up horizontal underground stems* (Iris, Lily of the Valley)

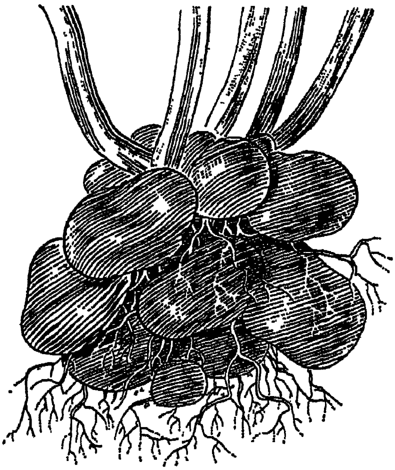


1. *Grafting* (Fruit trees)

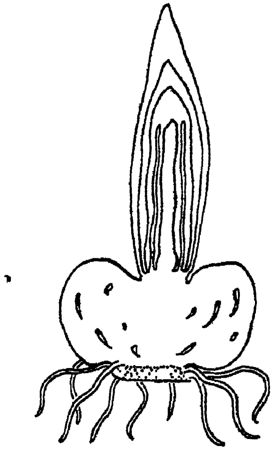


2. *Breaking up the roots* (Phlox, thrift)

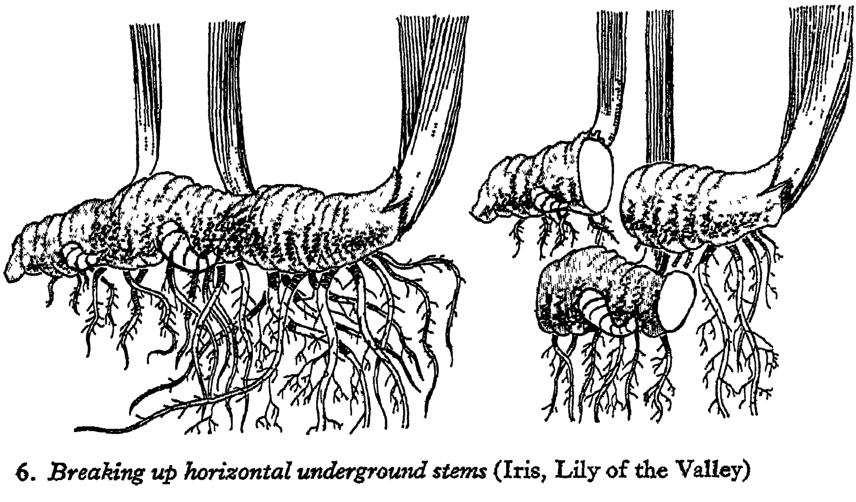
3. *Runners* (strawberries)



4. *Planting single swollen roots* (Dahlias) or *swollen stems* (Potatoes)



5. *Planting underground buds* (*bulbs*) (Daffodils, Shallots) *or underground stems* (Crocus corms)



6. *Breaking up horizontal underground stems* (Iris, Lily of the Valley)

When we make extra plants by breaking up our original ones, we call this method *vegetative reproduction.*

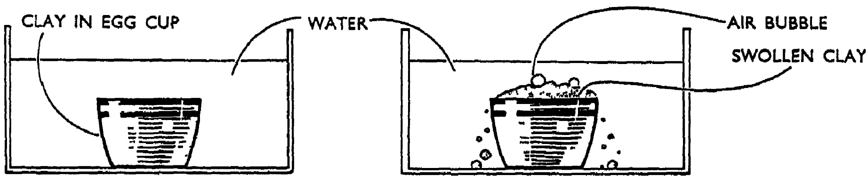
Plant Families. You will learn how to recognise some of the families of plants, in Book IV.

TEN QUESTIONS ABOUT THE GARDEN

1. What things should good garden soil contain?
2. What do you know about clay soil?
3. How could you improve clay soil?
4. How would you make compost? Why is it useful?
5. Why should you pull up weeds?
6. Why are earthworms good for the garden?
7. Say how seeds are scattered.
8. What things must seeds have if they are to germinate?
9. Name the three kinds of bees in a hive.
10. What do we mean by the words "herbaceous" and "perennials"?

THINGS TO DO

1. Powder up some dry garden clay. Fill a small eggcup with the clay and level the top with a ruler. Carefully place the eggcup in a glass dish of water. Watch what happens.

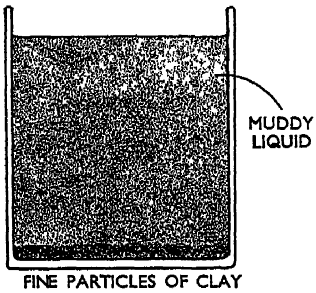


The swollen clay particles push out the air. Roots need air. Will good roots develop in wet clay soil?

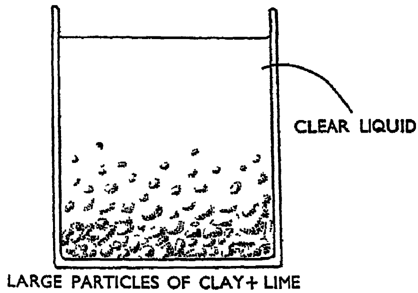
2. Make a small brick of garden clay. Place it on paper and draw round it. Leave the brick on the drawing for several days. What has happened to the brick? How do you think you could make it the size it was before?

When potters use clay to make pots they know that it will shrink as it dries. They make their pots bigger than they want them to be.

3. Mix a little clay soil with water. Stir well and pour into two jam jars. Add a teaspoonful of lime to one jar and watch the clay settle to the bottom in bigger particles.



Water and clay



Water, clay and lime

4. In Autumn collect 2 lbs. of dead leaves. Put them in a box in a shed. Collect another 2 lbs. of the same kind of leaves. Make a heap of these in the garden putting layers of leaves and soil as shown on p. 155. Water the heap often. Notice whether the leaves on the heap or those in the box rot first.

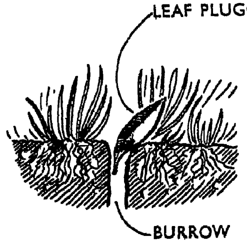
5. See if the soil in the garden needs lime by doing the acid test on p. 159.

6. After a holiday, pull up all the weeds in one flower bed. Count them. Try to discover their names. If you have already weeded the bed before the holiday you can say how long it took these weeds to grow. Measure the length and breadth of your flower bed and work out its area. Then you can work out the number of weeds per sq. yard. Compare your result with those of pupils weeding other beds.

7. Test a fresh damp wormcast with soil indicator. Also test the soil just below (use a trowel). Is there any difference? Can you explain your results?

8. Place an earthworm on a piece of rough brown paper. Hold the paper near your ear and listen to the scraping sound made by the worm's bristles as it moves along. Does a worm move as easily on glass? Can you think why this should be?

9. Look on the grass for dead leaves which the worm has dragged along with its mouth to plug the opening to its burrow. Also look for dead leaves with dark, softened edges, from which bits have been eaten. These may be leaves which the worm has "felt" all round with its mouth, softened with digestive juice and partly eaten. You may like to collect and press some of these to put with your notes about the earthworm.



10. Examine an earthworm and find the parts shown on p. 163.

11. Find how many earthworms are in one square yard of soil. Mark out one square yard on a lawn or flower bed, and water it all over with one quarter of an ounce of permanganate of potash dissolved in a can of water. Count the worms as they come to the surface.

12. Look on leaves of gooseberry bushes, or on the wild plant, ragwort, in May and June, for the brown and orange banded caterpillars of the Cinnabar moth.

13. Look for caterpillars of the Codlin moth in apples and pears.

14. Examine a plant from the garden and find all its parts. Mention the use of each part.

15. Carry out the experiment with a carrot on p. 170.

16. Look at pollen from different kinds of flowers under the microscope. Which of the flowers are pollinated by insects? How can you tell?

17. Scrape some pollen from the stigma of an Evening Primrose flower and examine it under the microscope. Notice that some of

the grains have grown a pollen tube. Find which other flowers show this also.

18. Look for tree seedlings in a wood. Notice that the first leaves are often different in shape from the later ones. Can you think why the first Beech leaves have this shape? (Beech has the same kind of germination as Sunflower.)

19. Find out from gardening books about the life stories of some of the garden pests you find. Make a leaflet to help gardeners to get rid of one of them.

20. Look at the leaflets issued by the Ministry of Agriculture, Fisheries and Food to help people look after their gardens.

21. Watch a bee visiting a flower. Does it go from one kind of flower to a different kind, or does it visit the same kind of flower many times before it goes back to the hive?

22. Write down the names of flowers which have a crowd of bees visiting them. Beside each write the colour of the flower. Can you say which colour the bees prefer? (You might like to draw or paint the flowers and so make a collection of paintings of "bee plants.")

23. If butterflies visit flowers in the garden, make a list of those they visit. These are "butterfly" plants.

24. You may see moths visiting flowers in the evening. What colour are these flowers? Can you think why?

25. Make a collection of butterflies and moths which visit your garden. Make drawings of the eggs on the food plant, the caterpillar, and if possible, the pupa or crysalis.

26. Ask a gardener to show you how and when to put a grease band on a fruit tree, or follow the instructions in "Adam the Gardener" and do it yourself.

27. *Making insect collections.* Other tiny insects may lay eggs on your dead insects. To prevent this, take a pin and a moth ball. Heat the head of the pin and push it into the moth ball. Then push the pin into the bottom of the storage box. The moth ball (made of naphthalene) will keep away other insects and preserve your collection.

28. From a gardening book or a seedsman's catalogue, find out what sprays are used for killing moths, greenfly, or any other pests you have in your school garden. Try to make up a spray and use it.

29. Examine a plant from the school garden. Find all its parts and make a labelled drawing of what you see.

30. Draw a tree bud which has corky bud scales. Keep the twig in water and notice what happens to the scales when the buds open.

31. Cut an onion from top to bottom. Find the dry scales on the outside, and the white juicy parts inside. These are the lower ends of the green leaves of the onion plant. Where do you think the food was made?

32. Collect a lot of seed cases (fruits). Sort them into groups:

1. Those whose seeds are scattered by wind.
2. Those whose seeds are scattered by animals.
3. Those whose seeds are scattered by explosion.

33. Collect a few seeds of different garden plants, put them into match boxes and name them. Look at them carefully and draw some of the most curious ones. Plant some of them in flower pots and watch them start to grow. Then you could transplant them to the garden.

34. Look at the root of a pea, bean, clover or lupin plant at the end of the summer. Notice the bumps (nodules) on it. These house colonies of bacteria which make extra protein inside the root (page 157).

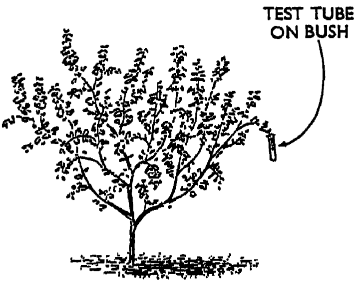
SOME EXPERIMENTS ON THE LIFE OF PLANTS

You have found from the carrot experiment on p. 170 that a sugar solution will pull water through the carrot cells. This process is called *osmosis*. Water gets into a root by a process rather like osmosis.

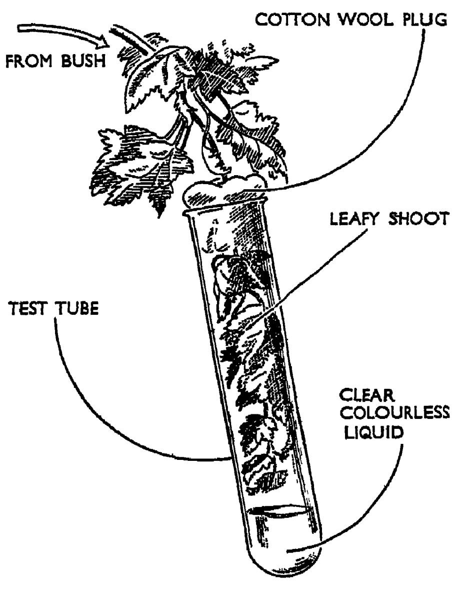
1. *Now you can do an experiment to see the path taken by the water through the plant.* Take a plant from the garden (Balsam is best, but any soft green plant will do). Stand it in a beaker with

its roots in red ink and leave for a few hours. Notice that the ink has risen up the stem to the leaves and flowers and coloured them. Cut the stem across. Can you see the red patches up which the ink has travelled? This is the *wood* of the plant. Cut across the root. Where is the wood in the root? Sketch the cut stem and root and label the wood in each.

2. *What happens to water which the plant does not use up?* Out in the garden push a leafy Blackcurrant shoot into a test tube and plug the top of the tube with cotton wool. After a few days, test the colourless liquid which has collected in the tube with blue cobalt chloride paper (see Book I). If there is enough liquid, you can find its boiling point and its freezing point. What is this colourless liquid?



Test tube on the bush



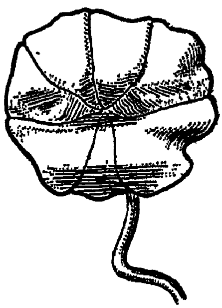
Test tube removed after a few days

3. *How does the water get out of the plant?* Hold a Nasturtium leaf by the stalk and plunge the round blade into hot water. Notice the tiny bubbles of air leaving the leaf. Each is coming from a pore

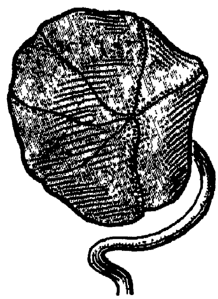
(stomate, which means "little mouth"). Which surface of the leaf is producing more bubbles? Which surface has more stomates? You found from Book I that water vapour and not liquid water is given out from leaves. In experiment 2 the vapour condensed to liquid in the tube. Can you think why? (see Book II—Humidity). (Oxygen and carbon dioxide pass through the stomates as well as water vapour.)

4. *A green leaf makes food in daylight.* Cover a Nasturtium plant growing in the garden, with a flower pot. Plug the hole to keep out the light. After several hours, pick one of the leaves, put it into hot water to kill it, then put it into warm methylated spirit to dissolve out the green colour. When the leaf is white, wash in water and put it into a dish of iodine solution. Pick another leaf from a Nasturtium plant which has been in the light. Kill and decolourize this leaf also. What do you discover about food making and light?

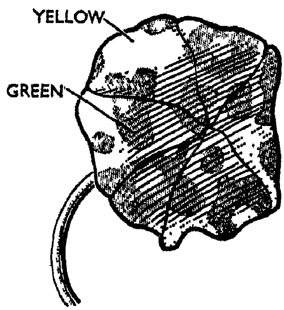
5. Can you think out an experiment to find if starch is made in leaves which are not green? Hint—Use a variegated Nasturtium leaf or any other thin yellow and green leaf. Do not forget to pick it during daylight, and draw it before you remove its colour!



Leaf 1. There is no starch because there was no light



Leaf 2. There is starch because there was light



Leaf 3. A variegated leaf

6. Repeat the experiment in Book II to show that green leaves give out oxygen while they make food.

7. *Watering plants with brine or strong solution of a fertiliser.* Transplant three healthy young cabbage plants into three small flower pots in good soil. Water them well and leave them out of doors for a week. Then dissolve one ounce of salt in half a pint of water and use this solution to water pot 1. Dissolve one ounce of a fertiliser, ammonium sulphate, in half a pint of water and water pot 2 with this. Water pot 3 with half a pint of water. Two days later compare the three plants. The strong salt and ammonium sulphate solutions have sucked water *out* of the roots. Can you now say why salt is useful as a weed killer if sprinkled on a path? Why can you not use it to destroy weeds in your garden beds?

8. *The use of soil salts to plants.* If your school has bottles of culture solutions, try to find out the special value of each kind of salt such as nitrate, phosphate, etc. Germinate radish seeds in small washed flower pots, and when the seedlings are about one inch high, begin to water the washed silver sand in which they are growing, with a different solution for each pot. Water pot 1 with the normal solution which contains all the salts chemists have found in the soil, in the correct amounts. Water pot 2 with the solution without nitrate, pot 3 with the solution without phosphate, pot 4 without sulphate, pot 5 without iron, and so on. After three weeks, examine your plants and decide the effects of depriving your plants of these different substances. Do not forget to examine the roots when your experiment is finished. Keep the pots out of doors if possible, and try to do this experiment in the Summer term. Water each pot with distilled water instead of the solution, every alternate day.

(*Note to the Teacher.* Sachs' culture powders can be bought from Messrs. Flatters and Garnett, 309 Oxford Road, Manchester. The contents of each tube have simply to be dissolved in the stated volume of distilled water.)

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